ELECTRONICS TECHNICIAN 3

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10188-B

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PREFACE

This training course is written for men of the U. S. Navy and Naval Reserve who are interested in qualifying for advancement to Electronics Technician, Third Class. Combined with the necessary practical experience, this training course will aid the Electronics Technician in preparing for the advancement-in-rating examination.

The qualifications for Electronics Technicians are included in appendix II. This training course contains information on each examination subject; and insofar as it is practical in a training course, information is, also included on each practical factor. Because examinations for advancement in rating are based on these qualifications, interested personnel should refer to them for guidance. The latest qualifications for advancement in rating should always be consulted.

The ET3 training course is prepared by the U. S. Navy Training Publications Center, Washington, D. C., which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by the Electronics Technician School (Class A) Naval Training Center, Great Lakes, Illinois; the Bureau of Ships; and other activites cognizant of electronic equipment and the duties of Electronics Technicians.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

READING LIST

NAVY TRAINING COURSES

Basic Electricity, NavPers 10086-A
Basic Electronics, NavPers 10087-A
Introduction to Electronics, NavPers 10084
Basic Handtool Skills, NavPers 10085-A
Blueprint Reading and Sketching, NavPers 10077-B
Mathematics, Vol 1, NavPers 10069-B
Mathematics, Vol 2, NavPers 10070-A

OTHER PUBLICATIONS

U. S. Navy Safety Precautions, Chapter 18 OPNav 34P1
BuShips Technical Manual Chapter 67

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education officer.* The following courses are recommended;

B150-02 Review Arithmetic
B151 Basic Ideas of Mathematics
B152 General Mathematics
C164 Algebra, Course 1
C166 Algebra for Problem Solving
C290 Physics I
B781 Fundamentals of Electricity
B885 Understanding Radio
B890 Radio Servicing, 1
B891 Elements of Radio Servicing

* "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty orders."

CHAPTER 1

ADVANCEMENT

This training course is designed to aid you in preparing for advancement to ET3. There are many requirements for advancement, and they will be discussed later in this chapter. The professional (technical) qualifications for advancement to ET3 used as a guide in the preparation of this course are current through Revision A of the Manual of Qualifications for Advancement in Rating, NavPers 18068-A. Military requirements for advancement are discussed in Basic Military Requirements, NavPers 10054, Military Requirements for Petty Officers 3 & 2, NavPers 10056, and Military Requirements for Petty Officers 1 & C, NavPers 10057.

Chapter 2 of this training course discusses electronics safety precautions, and chapter 3 discusses the electronics type designation system (AN system). Technical publications and records that concern the ET are discussed in chapter 4. Chapter 5 describes briefly the major electronics installations board ship, and includes information concerning their location and methods of installation. Chapters 6 and 7 discuss test equipment, and chapter 8 discusses switches and switching systems. Common operating adjustments for radio, teletype and facsimile and radar and loran equipments are discussed in chapters 9, 10, and 11. Maintenance procedures and techniques are discussed in chapters 12 and 13.

The remainder of this chapter presents information that will help you in preparing for advancement. Study this chapter carefully before beginning intensive study of the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The present enlisted rating structure, established in 1957, includes three types of ratings—general ratings, service ratings, and emergency ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

EMERGENCY RATINGS generally identify civilian occupational fields. Emergency ratings do not need to be identified as ratings in the peacetime Navy, but their identification is required in time of war.

THE ELECTRONICS TECHNICIAN RATING

Upon deciding to strike for ET, you selected one of the most interesting and challenging fields available to men in the Navy. Electronics Technicians maintain, repair, calibrate, tune, and adjust electronic devices and equipments. Advances in electronics continue to bring about improvements in these equipments, and new equipment is continually being developed. Thus the ET is a keyman in our modern Navy.

Electronics Technician rates are included in the personnel allowance for practically all Navy ships including repair ships and tenders. The rating was established in 1948, and includes service ratings ETR (radar) and ETN (communications) at petty officer 3 & 2 levels. For advancement to ET1 the candidate must be qualified in both service ratings. Enlisted classification codes for the rating are listed under group III in the Manual of Navy Enlisted Classifications, NavPers 15105.

The ET should have a good background in mathematics. If you are lacking in this area,

the mathematics training courses listed in the front of this course are recommended. Skill in the use of tools and test equipment will be acquired through performance of your daily duties. Gaining the necessary technical knowledge, and keeping abreast of the changes in your field, however, will require reading and studying in your spare time.

Also, upon advancement to ET3, you will be graded on your leadership and supervisory ability as well as your ability to perform your technical duties. Study the leadership principles and techniques discussed in Military Requirements for Petty Officers 3 & 2. Additional material concerning leadership for petty officers is available to you as a result of the current Navy leadership program. As you study the material containing leadership traits, keep in mind that probably none of our most successful leaders possessed all of these traits to a maximum degree, but a weakness in some traits was more than compensated for by strength in others. Critical self-evaluation will enable you to realize the traits in which you are strong, and the traits which you must strive to improve. Leadership principles can be taught, but a good leader acquires that quality only through hard work and practice. Your success as a leader will be decided for the most part by the success with which you have inspired others to learn and perform through your personal example.

ADVANCEMENT IN RATING

Some of the rewards of advancement in rating are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

But the advantages of advancing in rating are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement in rating? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and professional training courses.
3. Demonstrate your ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Demonstrate your KNOWLEDGE by passing a written examination on (a) military requirements and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the requirements for advancement can change. Check with your information and education officer to be sure that you know the most recent requirements.

Advancement in rating is not automatic. After you have met all the requirements, you are ELIGIBLE for advancement. You will actually be advanced in rating only if you meet all the requirements (including making a high enough score on the written examination) and if the quotas for your rating permit your advancement.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement in rating? You must study the qualifications for advancement, work on the practical factors, study the required Navy Training Courses, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) applicable Navy Training Courses. Figure 1-3 illustrates these materials; the following

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

<table>
<tr><th>REQUIREMENTS *</th><th>E1 to E2</th><th>E2 to E3</th><th>E3 to E4</th><th>E4 to E5</th><th>E5 to E6</th><th>E6 to E7</th><th>† E7 to E8</th><th>‡ E8 to E9</th></tr>
<tr><td>SERVICE</td><td>4 mos. service—or completion of recruit training.</td><td>6 mos. as E-2.</td><td>6 mos. as E-3.</td><td>12 mos. as E-4.</td><td>24 mos. as E-5.</td><td>36 mos. as E-6.</td><td rowspan="2">48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment.</td><td rowspan="2">24 mos. as E-8. 10 of 13 years total service must be enlisted.</td></tr>
<tr><td>SCHOOL</td><td>Recruit Training.</td><td></td><td>Class A for PR3, DT3, PT3. ǂAME 3</td><td></td><td></td><td>Class B for AGCA, MUCA, MNCA.</td></tr>
<tr><td>PRACTICAL FACTORS</td><td>Locally prepared check-offs.</td><td colspan="7">Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.</td></tr>
<tr><td>PERFORMANCE TEST</td><td colspan="2"></td><td colspan="4">Specified ratings must complete applicable performance tests before taking examinations.</td><td></td><td></td></tr>
<tr><td>ENLISTED PERFORMANCE EVALUATION</td><td colspan="2">As used by CO when approving advancement.</td><td colspan="6">Counts toward performance factor credit in advancement multiple.</td></tr>
<tr><td>EXAMINATIONS</td><td colspan="2">Locally prepared tests.</td><td colspan="4">Service-wide examinations required for all PO advancements.</td><td colspan="2">Service-wide, selection board, and physical.</td></tr>
<tr><td>NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)</td><td></td><td colspan="5">Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).</td><td colspan="2">Correspondence courses and recommended reading. See NavPers 10052 (current edition).</td></tr>
<tr><td rowspan="2">AUTHORIZATION</td><td colspan="2">Commanding Officer</td><td colspan="2">U.S. Naval Examining Center</td><td colspan="4">Bureau of Naval Personnel</td></tr>
<tr><td colspan="6">TARS are advanced to fill vacancies and must be approved by CNARESTRA.</td><td colspan="2"></td></tr>
</table>

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.
‡ 3 years obligated service required.
ǂ Effective 1 Jan. 1963.

5.1

Figure 1-1.—Active duty advancement requirements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
	FOR THESE DRILLS PER YEAR								
TOTAL TIME IN GRADE	48	6 mos.	6 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	24	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.		
DRILLS ATTENDED IN GRADE †	48	18	18	45	54	72	108	144	72
	24	16	16	27	32	42	64	85	32
TOTAL TRAINING DUTY IN GRADE †	48	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	24	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days		
PERFORMANCE TESTS				Specified ratings must complete applicable performance tests before taking examination.					
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 760, must be completed for all advancements.							
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.							
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.						Standard EXAM, Selection Board, and Physical.	
AUTHORIZATION		District commandant or CNARESTRA					Bureau of Naval Personnel		

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for drills and training duty.

5.2

Figure 1-2.—Inactive duty advancement requirements.

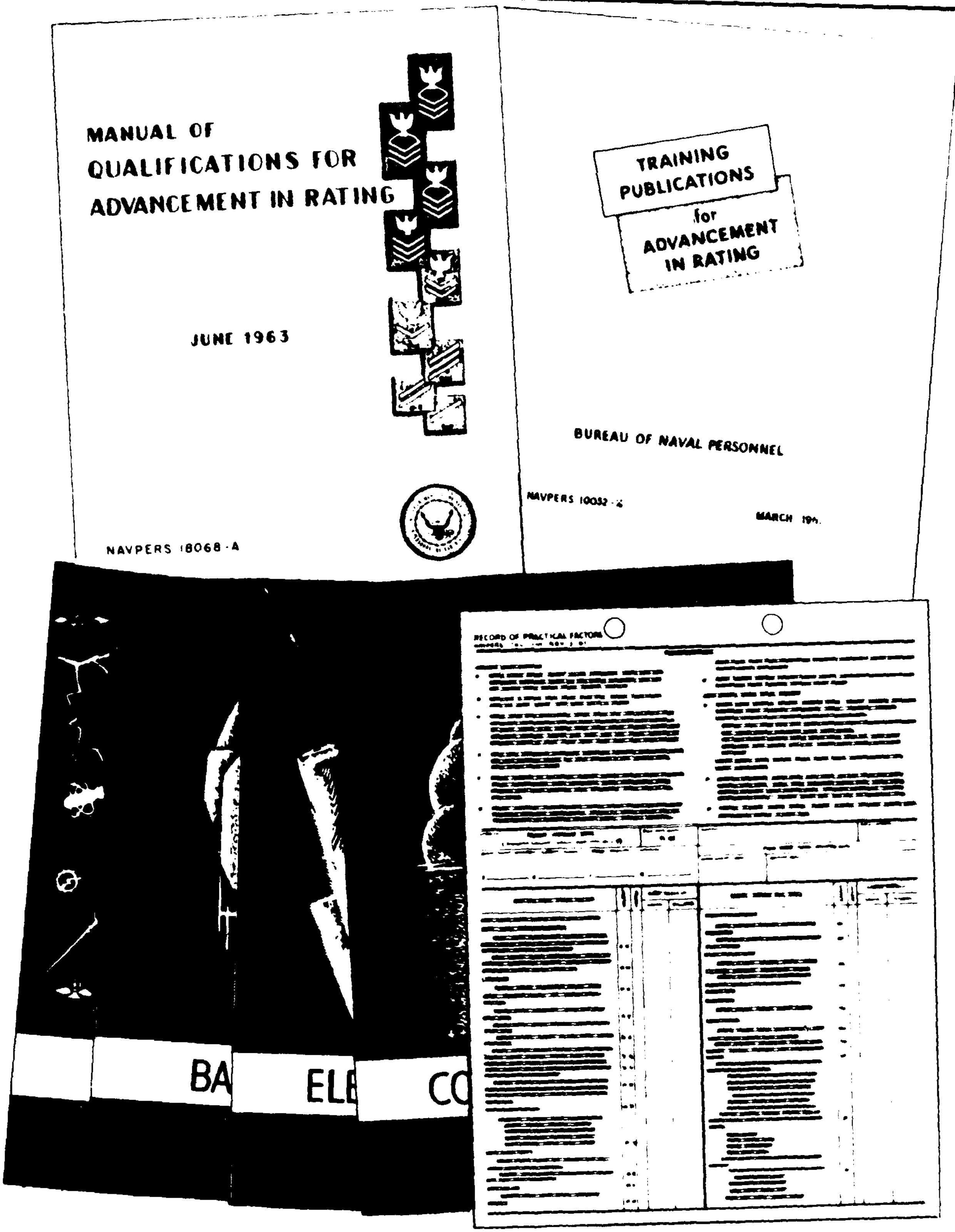


Figure 1-3.—Materials used in preparing for advancement. 5.3

sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068-A gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications.

MILITARY REQUIREMENTS apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

PROFESSIONAL QUALIFICATIONS are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

The professional qualifications for advancement in your rating are printed as an appendix at the back of this training course. Study these qualifications and the military requirements carefully. The written examination for advancement in rating will contain questions relating to the practical factors and the knowledge factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The professional qualifications for your rating which are printed as an appendix to this training course were current at the time the course was printed. By the time you are studying this course, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked the change number against an UP-TO-DATE copy of the Quals Manual.

Record of Practical Factors

Before you can take the servicewide examination for advancement in rating, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the RECORD OF PRACTICAL FACTORS, NavPers 760, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement in Rating, and revised forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, the NavPers 760 form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NavPers 10052

Training Publications for Advancement in Rating, NavPers 10052 (revised), is a very important publication for anyone preparing for advancement in rating. This bibliography lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval

Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NavPers 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a BuPers Notice has been issued to supplement NavPers 10052 for your rating.

The required and recommended references are listed by rate level in NavPers 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NavPers 10052, you will notice that some Navy Training Courses are marked with an asterisk (*). Any course marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement in rating. Each mandatory course may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the training course; or (3) in some cases, successfully completing an appropriate Class A school.

Do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of ALL ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating.

The references in NavPers 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Navy Training Courses

There are two general types of Navy Training Courses. RATING COURSES (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of ONE rating. SUBJECT MATTER COURSES or BASIC COURSES give information that applies to more than one rating.

Navy Training Courses are revised from time to time to keep them up to date technically. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether any particular copy of a Navy Training Course is the latest edition by checking the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061. (NavPers 10061 is actually a catalog that lists all current training courses and correspondence courses; you will find this catalog useful in planning your study program.)

Navy Training Courses are designed to help you prepare for advancement in rating. The following suggestions may help you to make the best use of this course and other Navy training publications when you are preparing for advancement in rating.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training course intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training course in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions: What do I need to learn about this? What do I already

know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement in rating?

5. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training course, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or on other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the Navy Training Course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondence course helps you to master the information given in the training course, and also helps you see how much you have learned.

10. Think of your future as you study Navy Training Courses. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rating; it is likely to be a waste of time, and may even be seriously misleading.

Technical publications that will be helpful as references and in preparing for advancement are discussed in chapter 4. Other training courses that will be helpful to you are listed in the front of this course.

Training film also furnishes a valuable source of supplementary information. A selected list of training films appears in appendix I of this training course. Other films that may be helpful are listed in the U. S. Navy Film Catalog, NavPers 10000 (revised).

CHAPTER 2

ELECTRONICS SAFETY PRECAUTIONS

Nothing in the ET training program can be more important to the individual ET than his own personal safety and the safety of his shipmates. Because this is such a personal matter, its importance should be obvious. In few other fields of work is the expression, "carelessness kills," more appropriate.

Electronic circuits are potentially dangerous even when the technician uses a great deal of care in his service work. The danger, however, varies inversely with the effectiveness of the safety precautions. Therefore, proven, recommended safety precautions must be observed.

When working on live equipment, watch what touches your body as well as what you touch with your hands.

Learn artificial respiration. *If you know it*, it may save your shipmate's life. If he knows it, it may save your life.

In cases of electric shock, artificial respiration must be given IMMEDIATELY to do any good. For example, power linemen are told to start artificial respiration before lowering the victim from the pole to the ground. This procedure saves valuable time.

Instructions for giving artificial respiration are included in the Standard First Aid Training Course, NavPers 10081.

Much material has been written on the subject of safety precautions; and much has been written especially for the benefit of electronics personnel.

All electronics personnel must become thoroughly familiar with United States Navy Safety Precautions, OpNav 34P1, including the latest changes; they should pay special attention to chapter 18. All electronics personnel must likewise become familiar with chapter 67 of the Bureau of Ships Technical Manual, NavShips 250,000, including the latest changes; they should pay special attention to section 5 of chapter 67.

Additional information that will be of value is contained in Electric Shock, its Cause and Prevention, NavShips 250-660-42; chapter 1 of the Electronic Installation Practices Manual, NavShips 900, 171, and in some issues of the Bureau of Ships Journal. Many issues of the Electronics Information Bulletin (EIB) also include safety information.

Some of the information contained in the following paragraphs is condensed from the previously mentioned references.

PERSONAL PROTECTION

The technician must not work on electrical (or electronic) equipment when his hands or clothing are wet. Never wear loose or flapping clothing or clothing with exposed zippers or metal fasteners when working on electronic equipment. The same is true of rings, wristwatches, bracelets, and similar metal items. Another very important item is the matter of shoes. Never wear thin-soled shoes and shoes with metal plates or hobnails when working on electronic equipment.

Work must never be done on live circuits where the voltage exceeds 30 volts except in case of emergency. Under emergency conditions when work must be done on live circuits, every precaution must be taken to prevent accidental grounds. Wear rubber gloves and use properly insulated tools; cover the deck with an approved insulating material; and make sure that at least one other person is present at all times. All persons must be thoroughly familiar with approved methods of rendering first aid and artificial respiration. Specific instructions pertaining to work on live circuits are contained in chapter 18 of United States Navy Safety Precautions, OpNav 34P1.

Danger signs and suitable guards must be provided to prevent personnel from coming in accidental contact with high voltages. Danger

signs must also be used to warn personnel servicing electronic material aloft against the possible presence of explosive vapors in certain locations and against the POISONOUS EFFECTS OF SMOKE AND STACK GASES.

According to OpNav 34P1, on all circuits where the voltage is in excess of 30 volts, and where the deck or walls are of metallic construction, the worker must be insulated from accidental grounding by the use of approved insulating material. Whenever work of a nature other than electrical is performed in the vicinity of exposed electrical circuits, see that suitable insulating barriers are provided to prevent accidental contact with the circuits. Dry wooden stools or platforms may be used to prevent the possibility of contact between the workmen's shoes and a wet or damp floor.

Other protective measures include (1) covering metal tool handles with rubber insulating tape; (2) ensuring that fuse boxes are securely closed except when work is being done on them; (3) checking the resistance between the metal bases, frames, and so forth of electronic equipment and ground at regular intervals and after repair work has been done; and (4) being sure that safety devices such as interlocks, overload relays, and fuses are not altered or disconnected except for replacement (no safeguard circuit is to be modified without specific authority).

In connection with insulating metal tool handles with rubber insulating tape, it is also necessary to insulate the shanks of certain screwdrivers (particularly those used inside electronic equipment) with insulating sheaths. Only 3/16 of an inch of the blade need be exposed. Where it is not practicable to tape or otherwise insulate a surface, electricians' insulation varnish may be used.

There are certain special precautions against electric shock that must be taken. Certain pieces of equipment (for example, brushes, dusters, and brooms) not generally considered to be conductive can be dangerous, and the necessary precautions must be taken. Sufficient illumination is very important, and so is keeping one's attention directed to the work being done. Do not trust equipment insulation to protect you from high voltage when work is to be performed, and keep alert to the possibility of accidental grounds or shorts.

When working on live circuits, exercise as much care with low voltages as with high voltages; and never take a shock intentionally from any voltage regardless of how small it may be.

GENERAL ELECTRONICS SAFETY PRECAUTIONS

Because of the constant use of radio aboard ship the following precautions for radio-frequency circuits should be observed: (1) Energized high voltage output circuits should not be broken except when absolutely necessary and authorized by a qualified officer; and (2) when other transmitting equipment is in use at the same installation or close by, ETs should be on the alert to prevent shock, burns, or other injury to personnel due to energy picked up from adjacent antennas or equipment (certain circuits may have to be grounded for safety reasons).

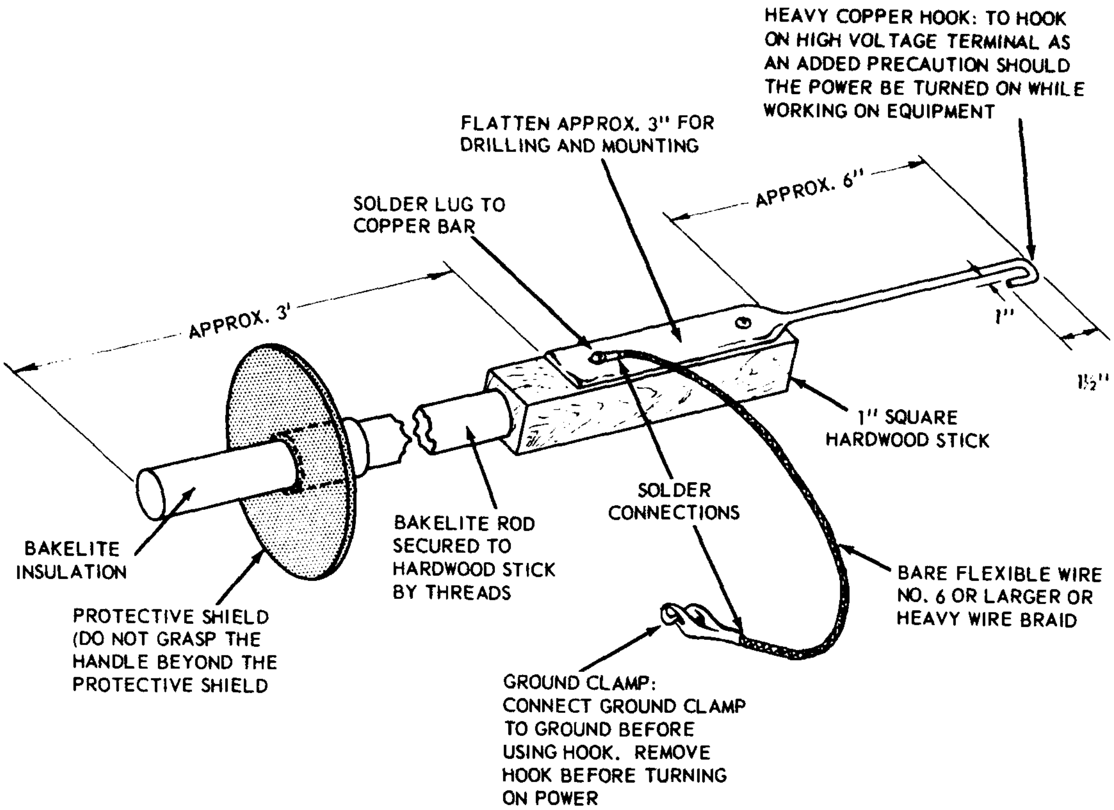
Electronic detonators or igniters, electrically fired rocket motors, and electric fuzes (ordnance) must not be located in the same compartment with or be exposed within 5 ft of any exposed electronic transmitting apparatus, or exposed antenna, or antenna lead aboard ship or at a shore electronics activity. No danger due to r-f potentials exists with detonators of any type while they are in a properly covered metal container.

Capacitors are potentially dangerous. Before touching a capacitor, which is connected to a deenergized circuit (or which is disconnected entirely), short-circuit the terminals to make sure that the capacitor is completely discharged. A suitably insulated shorting stick should be used for this purpose (fig. 2-1).

The primary function of the shorting stick is to pass the discharge current from a capacitor through the ground wire to ground, NOT through the body of the person discharging the capacitor. The hook enables the technician to fasten the stick to the high-voltage terminal so that it can serve as an added protection while work is in progress. Connect the ground clamp to ground BEFORE using the hook.

Some shore stations have provided a shorting stick at each transmitter enclosure. In each case it is so placed that the technician must remove the shorting stick before he can gain access to the equipment.

No person should reach within or enter energized electronic equipment enclosures for the purpose of servicing or adjusting, except when prescribed by official applicable technical manuals and then not without the immediate presence and assistance of another person capable of rendering aid in an emergency.



1.1

Figure 2-1.—Diagram of shorting stick.

When the ship is in drydock, the electronic equipment on board may be energized only with the permission of the docking officer.

COMMON SAFETY FEATURES IN ELECTRONIC EQUIPMENT

The ET should be aware of the safety features that are generally included in electronic equipment. There is a tendency on the part of design people to pay more attention to safety measures when the equipment is to be used by unskilled persons than when it is to be used by skilled persons, but there is always the possibility that an accident will happen to a skilled, but unalert person. This is a matter to keep in mind; and the ET must remember that safety devices cannot always be counted upon to function.

Some of the common safety features are interlock switches, bleeder resistors, insulated controls, and power-line safety devices.

INTERLOCK SWITCHES

The interlock switch is ordinarily wired in series with the power-line leads to the electronic power supply unit, and is installed on the lid or door of the enclosure so as to break the circuit when the lid or door is opened. A true interlock switch is entirely automatic in action; it does not have to be manipulated by the operator.

Multiple interlock switches, connected in series, may be used for increased safety. One switch may be installed on the access door of a transmitter, and another on the cover of the power-supply section. Complex interlock systems are provided when several separate circuits must be opened with safety.

Because electronic equipment may have to be serviced without deenergizing the circuits, interlock switches are so constructed that they can be disabled by the technician. However, they are generally located in such a manner that a certain amount of manipulation is necessary in order to operate them.

BLEEDER RESISTORS

A bleeder resistor is often connected across the output terminals of high-voltage d-c power supplies. It is used to bleed the dangerous charges off the filter capacitors because a high-grade filter capacitor can maintain its charge for a long period of time.

The bleeder current is an added drain on the power supply, but the system is designed to withstand this additional burden.

In some equipments where large, high-voltage capacitors cannot be effectively shunted by bleeder resistors, the technician must discharge these capacitors before working on the high-voltage circuits. For this purpose special shorting sticks are used.

The technician must keep in mind the possibility that the bleeder resistor may burn out and thus become useless as a protective device. Filter capacitors must be discharged as a matter of routine when repair work is to be done. Do not depend on the bleeder; it is merely an added protection.

INSULATED CONTROLS

Metal knobs, dials, switches, and adjustment screws are generally used only in equipment of the "cold chassis" type; they are not used with a-c/d-c devices.

Even when insulated knobs are used, short setscrews, which do not extend beyond the recessed opening in the knob, are used to prevent the operator's fingers from coming in contact with a possible live circuit.

Rheostats and potentiometers in high-voltage circuits are placed far enough back of the panel to permit an insulated shaft coupling between the device and the control knob. Common examples are the focus, intensity, and beam-centering controls of an oscilloscope.

POWER-LINE SAFETY MEASURES

Only approved line cords in good condition should be used. Such cords must be protected with insulating grommets at the point where they pass through the chassis or panel.

In addition to the external fuses, equipments are usually supplied with one or more internal fuses.

GROUNDING OF EQUIPMENTS AND COMPONENTS

USE OF GROUNDED TYPE PLUGS (AND RECEPTACLES)

Navy specifications for portable tools require that the electric cord for such tools be provided with a distinctively marked ground wire in addition to the conductors for supplying power to the tool. The end of the ground wire within the tool must be connected to the tools r housing. The other end must be connec a positive ground. For this ground conne use the specially designed grounded type plu and receptacles, which automatically make this connection when the plug is inserted in the receptacle.

Portable tools not provided with the grounded type plug, and miscellaneous portable electric equipments, which do not have a cord with a grounded conductor and grounded plug, must be provided with a 3-conductor cord and with a standard Navy grounded type plug. Connect the ground wire to a positive ground so that the total resistance from the tool enclosure to the ground to which it is connected does not exceed a small fraction of an ohm.

Because the ET is responsible for the portable power tools assigned to his division, he must be familiar with the Bureau of Ship's approved methods of installing plugs and cords. The methods are spelled out in detail in Article 60-27 of the Bureau of Ships Technical Manual. The following information is condensed from this article.

All 115-volt or 230-volt single-phase a-c and all 115-volt or 230-volt two-wire d-c electrically operated equipment now on board ship that does not have a cord with a grounding conductor and grounded plug, and all such equipment subsequently issued to the ship without a cord that has a grounding conductor and grounded plug, should be provided with a three-conductor flexible cable with standard Navy grounded plug, type D-2-G, shown on Bureau of Ships plan 9-S-4440-L. The three-conductor flexible cable should be type SO or ST color

coded black, white, and green, as listed in the Navy Stock List of General Stores, group 61.

All 115-volt 3-phase electrically operated portable equipment now on board ship or subsequently issued that does not have a cord with a grounding conductor and grounded plug should be provided with a type FHOF four-conductor flexible cable color coded black, white, red, and green, with standard Navy grounded plug, type EEE-125, shown on Bureau of Ships plan 9-S-4861-L.

The length of the cord for portable tools should be 25 feet. The green conductor should be used for the grounding conductor.

Extreme care must be exercised to see that the ground connection is made correctly. If the grounding conductor (green), which is connected to the metallic equipment casing, is connected by mistake to a line contact of the plug, a dangerous potential will be placed on the equipment casing. This might easily result in a fatal shock to the operator. To guard against this danger, the connections must be tested after they have been made, to make certain that the leads are connected properly and that a good ground is assured.

GROUNDING ELECTRONIC EQUIPMENT CASES

Ungrounded electronic equipment cases create an unnecessary hazard and frequently produce electronic interference. All missing ground connections must be replaced, and all ground connections must be checked with an ohmmeter.

GROUNDING WORKBENCHES

Special precautions must be taken to ground workbenches (when used for the repair of electronic equipment) by providing two or more ground straps symmetrically placed at diagonally opposite corners or posts, using low-resistance flexible braid securely welded or bolted to steel deck or bulkhead. After completing the grounding of the bench, test it with a low-reading ohmmeter for positive grounding. Positive ground will be indicated by a low meter reading.

PRECAUTIONS AGAINST ACCIDENTAL ENERGIZING

SECURING SWITCHES

When electrical equipment is to be worked on, it must be disconnected from the source of supply by opening main or branch supply switches, circuit breakers, or cutouts so as to completely eliminate the possibility of current flowing to the equipment. Switches, circuit breakers, or cutouts opened for this purpose must be secured in the open position and must have tags attached. Only the individual placing the tag may remove it and reenergize the circuit. Specific instructions are given in United States Navy Safety Precautions, OpNav 34P1, chapter 18.

INDUCED VOLTAGES

The use of electronic equipment in the frequency range of 30 megacycles and below will cause voltages to be induced in the standing rigging and other portions of the ship's structure, which, under certain conditions, are considered hazardous.

The voltages caused by resonant circuits set up in a ship's structure or rigging will cause shock to personnel, or produce open sparks when contact is made or broken—for example, when the circuit is opened, or when metallic objects make contact with the structure.

Although there are too many variables to give even an approximation of the voltages that may be encountered, the following examples are cited: (1) Excessive r-f pickup from ship antennas has been noted on smokestack guys, davit head spans, and the like; (2) a similar high-frequency pickup has been observed on board ship, particularly carriers, when the length involved in reeling in or paying out wire cable and wire hausers becomes resonant to the emitted frequency; and (3) it has been discovered that flammable liquids may be ignited in close proximity to an energized radar antenna if the liquid is in a metal container or near metal objects.

PRECAUTIONS WHEN WORKING ON ANTENNAS

Personnel should keep clear of r-f fields of exposed antennas. Under no circumstances should personnel approach closer than 1 foot

to a radio antenna unless it is definitely established that the antenna is not energized.

Specific instructions covering working aloft are given in Section 3, chapter 18, of United States Navy Safety Precautions, OpNav 34P1, a portion of which is included in the following paragraphs.

"Before any work may be done aloft, authorization must be obtained from the commanding officer. (The OOD usually gives permission for the commanding officer.) While antennas are energized by radio transmitters, men shall not be permitted to go aloft except by means of ladders and platforms rendered safe by grounded handrails or similar structures. Before sending men aloft, except as noted previously, the commanding officer shall direct the communication watch officer to secure the proper transmitter in order to render safe this area, and shall notify the engineer duty officer that men will be working in a prescribed area aloft in order that the engineer duty officer may take the necessary precautions to prevent the boiler safety valves from lifting (these are vented up the stack). Until he has received a report from the communication watch officer that the proper transmitters are secured, the commanding officer shall permit no man to go aloft. After the work has been completed, a report shall be made to the commanding officer, and his authorization must be obtained before the circuit is again energized.

"Radar and other antennas which rotate or swing through horizontal or vertical arcs may cause men working aloft to fall. Therefore, the motor switches which control the motion of these antennas shall be locked open and tagged before men are permitted to ascend or go within reach of them."

In connection with antennas it is extremely important to maintain a safe distance (perhaps hundreds of feet) in the field of an antenna of a high-powered radar set. Minimum safe distances from the various radar antennas are listed in chapter 67 of the Bureau of Ships Technical Manual, and EIB-558 dated 10 April 1961.

Under no circumstances should a person look into a waveguide of a radar set when the power is on. It is well to realize, too, that X rays are generated at the surface of cathode-ray tubes. At voltages of 20,000 volts or less, the glass is a shield. Above 20,000 volts the glass is progressively a poorer shield as the voltage goes up. Looking directly at a 30,000-volt projection cathode-ray tube is definitely dangerous, especially at a short distance (2 ft).

PRECAUTIONS WHEN HANDLING ELECTRON TUBES

CATHODE-RAY TUBES

The use of larger cathode-ray tubes has increased the danger of implosion, flying glass, and injury from high voltage. The danger is greatly reduced if the tubes are properly handled. If they are handled carelessly, struck, scratched, or dropped, they can very well become an instrument of severe injury or death. The following precautions should be taken: (1) Goggles should be worn to protect the eyes from flying glass particles, (2) suitable gloves should be worn, and (3) no part of the body should be directly exposed to possible glass splinters caused by implosion of the tube. (The coating on some tubes is poisonous if absorbed into the blood stream.)

Cathode-ray tubes must not be unnecessarily exposed to possible damage. When a tube is being unpacked, remove it from the packing box with caution, taking care not to strike or scratch the envelope. Insert it into the equipment socket cautiously, using only moderate pressure. When the tube must be set down, it is important that it be placed on a clean, soft padding. If special tube-handling equipment is available, it should be used according to instructions.

RADIOACTIVE ELECTRON TUBES

Poisoning from radioactive materials contained in electron tubes such as radiac, spark gap, TR, glow lamp, and cold cathode tubes may be of 3 types:

1. ASSIMILATION—Eating, drinking, or breathing radium or radium compounds or absorbing them through cuts. Radium-bearing dust, which may be present in certain tubes, is dangerous in this respect.

2. BREATHING RADON—Radon is a tasteless, odorless, colorless gas that is given off by radium and radium compounds at all times. When breathed into the lungs it may cause severe injury.

3. RADIATION—Radium and radium compounds give off harmful, invisible radiations that can cause dangerous burns.

Useless unbroken electron tubes containing radioactive material are treated as any other radioactive waste material. Broken radioactive electron tubes are disposed of in accordance with BuShips Instruction 5100.5 of 28 November 1955. Additional instructions concerning handling, storage, and disposition of radioactive electron tubes are contained in BuShips letter S67/9-11(871C), ESO Instruction 5100.1, and NavMed P-1325.

PRECAUTIONS TO BE OBSERVED WHEN PAINTING ELECTRONIC EQUIPMENT

Adequate ventilation must be provided for all enclosed compartments in which painting is to be done. Exhaust ventilators as well as power blowers should be used. Blowers should be so arranged as to ensure rapid and complete removal of all explosive, combustible, and/or toxic vapors which may be present. Vapors must be exhausted in such a way that they will not be sucked into any of the ship's supply vents which may be running, or in any way contaminate other areas.

Where paint vapors or fumes are known to be explosive, any electrical equipment used in the vicinity of the painting operations in enclosed compartments must be of the explosion-proof type. Do not permit smoking or allow any type of work that may produce flames or sparks to be performed within the danger area.

Maintain good housekeeping practices and keep all unnecessary objects and materials picked up and out of the way. Particular attention must be given to rags, sweepings, waste, etc., which may be paint-saturated or contaminated. These materials must be placed in covered metal containers or buckets containing water.

The exits to the compartment in which painting is being done must not be blocked in any manner. Adequate firefighting equipment must be at hand.

PRECAUTIONS IN USING SOLVENTS

Carbon tetrachloride is definitely toxic, actually about four times as toxic as carbon monoxide, and serious accidents have resulted from the improper use, storage, and handling of this solvent.

A new solvent, methyl chloroform, has been approved for cleaning electrical and electronic equipment. It is now available from General Stores, and should be used in place of the more dangerous carbon tetrachloride.

Even though methyl chloroform is less toxic than carbon tetrachloride, the solvent does present some hazards to personnel, and the following precautionary note is required on the container label:

"Caution—Use with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid prolonged or repeated contact with skin. Do not take internally."

The solvent may be applied by wiping, brushing, or spraying. Methyl chloroform, like carbon tetrachloride, will attack electrical insulating materials, particularly the air-dried varnishes. Therefore contact time should be limited.

SOME SAFETY RULES TO REMEMBER

1. Do not rely on safety devices such as interlocks and high-voltage relays.
2. Do not work alone on high-voltage circuits.
3. Observe all warning signs.
4. Do not intentionally come in contact with an energized circuit.
5. Avoid working on energized circuits.
6. Do not smoke, eat, or drink while painting.
7. Remember that solvents are potentially dangerous.
8. Use a shorting stick for discharging capacitors.
9. Use approved fuse pullers.
10. The appearance of the work is a measurement of the worker's ability; the same is true of the work space.
11. Remember that personnel may be killed or injured by high-voltage equipment that is assumed to be off. Take nothing for granted. Make certain that the power is off by securing the power-line switch in the OFF position.
12. Observe carefully the instructions about tagging open switches. The following is quoted from the Bureau of Ships Technical Manual:

"When any electronic equipment is to be overhauled or worked on, the main supply switches or cutout switches in each circuit from which power could possibly be fed shall be secured in the open (or safety) position and tagged. The tags shall read 'This circuit was ordered open for repairs and shall not be closed except by direct order of ______' (usually the person making, or directly in charge of,

the repairs). After the work has been completed, the tag or tags shall be removed by the same person.

"When more than one repair party is engaged in the work, a tag for each party shall be placed on the supply switch. Each party shall remove only its own tag upon completion of the work.

"When switch-locking facilities are available, the switch shall be locked in the open (SAFETY) position and the key retained by the person doing the work so that only he, or a person designated by him, can remove the lock and restore the circuit."

13. Even after switches have been opened and tagged, make an additional check at the equipment with a voltmeter known to be in good working order to ensure that the correct switch or switches have been opened.

14. Remember that aboard ship a person must exercise the greatest precaution when working with electrical circuits because of the metal structure (good ground), dampness, and crowded working conditions. This does not mean that a technician should be less cautious at shore stations. He should be cautious whenever he works with electricity; but, in general, the chances of being injured aboard ship are greater if the necessary additional precautions are not taken.

15. Be thoroughly familiar with OpNav 34P1 (United States Navy Safety Precautions), especially chapter 18; section 5 of chapter 67 of the Bureau of Ships Technical Manual, NavShips 250,000; and the Standard First Aid Training Course (NavPers 10081), especially those sections dealing with the treatment for electrical shock and burns.

CHAPTER 3

COMPONENT AND EQUIPMENT NOMENCLATURE AND DESIGNATIONS

The following information, condensed from chapter 67 of Bureau of Ships Technical Manual, NavShips 250,000, will be helpful to ETs.

JOINT ELECTRONICS TYPE DESIGNATION SYSTEM (AN SYSTEM)

The Electronic Type Designator System (AN System) for electronic equipment was adopted in 1943. The system is designed to:

1. Be logical in principle so that the nomenclature type numbers will be readily understood, and the operation of the armed forces supply services will be facilitated.
2. Be flexible and sufficiently broad in scope to cover present types of equipment and new types and uses of equipment that will be developed in the future.
3. Avoid conflict with nomenclature at present assigned to the equipment used by the armed services.
4. Provide adequate identification on nameplates with or without the name part of the nomenclature.
5. Provide a ready means of identifying equipment in correspondence and other types of communication.

The system is designed so that its indicators will tell at a glance many things that pertain to the item. For example, it tells whether the item is a SET or a UNIT and such other information as where it is used, what kind of equipment it is, and what it is used for. (See table 3-1.)

SET IDENTIFICATION

To explain the system, a typical example of set nomenclature, Radar Set AN/APS-2, is included in table 3-2. Thus, Radar Set AN/APS-2 is a search radar set installed and operated in an aircraft.

Other equipments in the same category are the AN/APS-4 and AN/APS-6. Another set of a different category is the AN/SRC-1 which, as indicated in table 3-1, is a shipboard radio communications set for receiving and transmitting.

To identify a set that has been modified, but which still retains the basic design and is interchangeable with the unmodified set, a modification letter is used (see table 3-1, column 5). Thus, if Radar Set AN/APS-2 is modified, it becomes AN/APS-2A. The next modification would be the AN/APS-2B, and so on.

A special indicator (see table 3-1, column 6) is used when the only change to a set is in its input power, or when it is an experimental or a special model. For example, if the same basic design is kept but the input power is changed from 13 volts to 26 volts, the letter "X" is added to the nomenclature, as AN/APS-2AX. The second power input change would be identified by the letter "Y."

A special indicator (T) for training sets is also available and is used in conjunction with the other indicators to show that it is a training set for a specific equipment. Likewise, it may be used to indicate a trainer for a special family of equipment. For example, the first training set for the AN/APS-2 would be AN-APS-2T1.

The system also provides for identifying a series of sets by the use of parentheses after the type number. Thus, the AN/APS-2( ) refers to the AN/APS-2 set and all its modifications such as the AN/APS-2A, AN/APS-2B, as well as its experimental versions such as the AN/APS-2(XB-1).

Experimental sets are identified by the use of the development organization indicators (see table 3-1, column 6). A number is used to indicate a particular developmental or reproduction model. Thus, the first developmental model of the AN/APS-2 could be identified as the AN/APS-2(XB-1), assuming, of course, that the Naval Research Laboratory did the work.

Table 3-1.—Equipment Indicator Letters.

1	2	3	4	5	6
Installation	Type of Equipment	Purpose	Model Number	Modification Letter	Miscellaneous Identification
A—Airborne (installed and operated in aircraft) B—Underwater mobile, submarine C—Air transportable (inactivated, do not use) D—Pilotless carrier F—Fixed V—Ground, general ground use (include two or more ground type installations) K—Amphibious M—Ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment) P—Pack or portable (animal or man)	A—Invisible light, heat radiating B—Pigeon C—Carrier D—Radiac E—Nupac (nuclear protection and control) F—Photographic G—Telegraph or teletype I—Interphone and public address J—Electro-mechanical (not otherwise covered) K—Telemetering L—Countermeasures M—Meteorological N—Sound in air P—Radar Q—Sonar and underwater sound R—Radio S—Special types, magnetic, etc., or combinations of types T—Telephone (wire) V—Visual and visible light W—Armament (peculiar to armament, not otherwise covered)	A—Auxiliary assemblies (not complete operating sets used with or part of two or more sets or sets series) B—Bombing C—Communications (receiving and transmitting) D—Direction finder and/or reconnaissance E—Ejection and/or release G—Fire control or searchlight directing H—Recording and/or reproducing (graphic meteorological and sound) L—Searchlight control (inactivated, use "G") M—Maintenance and test assemblies (including tools) N—Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach and landing) P—Reproducing (inactivated, do not use) Q—Special, or combination of purposes	1 2 3 4 Etc.	A B C D Etc.	X, Y, Z —change in input voltage, phase, or frequency Experimental indicators XA—Communications—Navigation Laboratory, WADC, Dayton, Ohio XB—Naval Research Laboratory, Washington, D.C. XD—Cambridge Research Center, Cambridge, Mass. XF—Frankfort Arsenal, Philadelphia, Pa. XG—U.S.N. Electronic Laboratory, San Diego, Calif. XH—Aerial Reconnaissance Laborabory, WADC, Dayton, Ohio XJ—Naval Air Development Center, Johnsville, Pa. XK—Flight Control Laboratory, WADC, Dayton, Ohio XL—Signal Corps Electronics Research Unit, Mountain View, Calif.

Table 3-1.—Equipment Indicator Letters—Continued.

1	2	3	4	5	6
Installation	Type of Equipment	Purpose	Model Number	Modification Letter	Miscellaneous Identification
S—Water surface craft T—Ground, transportable U—General utility (includes two or more general installation classes, airborne, shipboard, and ground) V—Ground, vehicle (installed in vehicle designed for functions other than carrying electronic equipment etc., such as tanks) W—Water surface and underwater	X—Facsimile or television	R—Receiving, passive detecting S—Detecting and/or range and bearing T—Transmitting W—Control X—Identification and recognition			XN—Department of the Navy, Washington, D. C. XO—Redstone Arsenal, Huntsville, Ala. XP—Canadian Department of National Defense, Ottawa, Canada XS—Electronic Components Laboratory, WADC, Dayton, Ohio XU—U.S.N. Underwater Sound Laboratory, Fort Trumbull, New London, Conn. XW—Rome Air Development Center, Rome, N.Y. XAN—Naval Air Facility, Indianapolis, Ind. For complete details see MIL-STD-196

Table 3-2.—Designation For Radar Set AN/APS-2.

Radar Set	AN/	A	P	S-	2
Item name as prescribed	A major equipment	See the designated column in table —			Second equipment in this category (col. 4)
		Airborne (col. 1)	Radar (col. 2)	Search (col. 3)	

COMPONENT IDENTIFICATION

So far, consideration has been given only to the indicators used in SET nomenclature. Indicators for major COMPONENTS of a set are now considered.

Components are identified by means of indicating letters (which tell the type of component it is) (see table 3-3), a number (which identifies the particular component), and finally the designation of the equipment of which it is a part or with which it is used.

Table 3-3.—Table of Component Indicators.

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
AB	Supports, Antenna	Antenna mounts, mast bases, mast sections, towers, etc.
AM	Amplifiers	Power, audio, interphone, radio frequency, video, electronic control, etc.
AS	Antennae, Complex	Arrays, parabolic type, masthead, etc.
AT	Antennae, Simple	Whip or telescopic, loop, dipole, reflector, etc.
BA	Battery, primary type	B batteries, battery packs, etc.
BB	Battery, secondary type	Storage batteries, battery packs, etc.
BZ	Signal Devices, Audible	Buzzers, gongs, horns, etc.
C	Controls	Control box, remote tuning control, etc.
CA	Commutator Assemblies, Sonar	Peculiar to sonar equipment
CB	Capacitor Bank	Used as a power supply
CG	Cable Assemblies, R.F.	R.F. cables, waveguides, transmission lines, etc., with terminals
CK	Crystal Kits	A kit of crystals with holders
CM	Comparators	Compares two or more input signals
CN	Compensators	Electrical and/or mechanical compensating, regulating or attenuating apparatus
CP	Computers	A mechanical and/or electronic mathematic calculating device
CR	Crystals	Crystal in crystal holder
CU	Couplers	Impedance coupling devices, directional couplers, etc.
CV	Converters (electronic)	Electronic apparatus for changing the phase, frequency, or from one medium to another
CW	Covers	Cover, bag, roll, cap, radome, nacelle, etc.
CX	Cable Assemblies, Non-R.F.	Non-R.F. cables with terminals, test leads, also composite cables of R.F. and non-R.F. conductors
CY	Cases and Cabinets	Rigid and semirigid structure for enclosing or carrying equipment

Table 3-3.—Table of Component Indicators—Continued.

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
D	Dispensers	Chaff dispensers
DA	Load, Dummy	R.F. and non-R.F. test loads
DT	Detecting Heads	Magnetic pick-up device, search coil, hydrophone, etc.
DY	Dynamotors	Dynamotor power supply
E	Hoists	Sonar hoist assembly, etc.
F	Filters	Band-pass, noise, telephone, wave traps, etc.
FN	Furniture	Chairs, desks, tables, etc.
FR	Frequency Measuring Devices	Frequency meters, tuned cavity, etc.
G	Generators, Power	Electrical power generators without prime movers. (See PU and PD.)
GO	Goniometers	Goniometers of all types
GP	Ground Rods	Ground rods, stakes, etc.
H	Head, Hand, and Chest Sets	Includes earphone
HC	Crystal Holder	Crystal holder less crystal
HD	Air Conditioning Apparatus	Heating, cooling, dehumidifying, pressure, vacuum devices, etc.
ID	Indicators, Non-Cathode-Ray Tube	Calibrated dials and meters, indicating lights, etc. (See IP.)
IL	Insulators	Strain, standoff, feed-through, etc.
IM	Intensity Measuring Devices	Includes SWR gear, field intensity and noise meters, slotted lines, etc.
IP	Indicators, Cathode-Ray Tube	Azimuth, elevation, panoramic, etc.
J	Junction Devices	Junction, jack and terminal boxes, etc.
KY	Keying Devices	Mechanical, electrical and electronic keyers, coders, interrupters, etc.
LC	Tools, Line Construction	Includes special apparatus such as cable plows, etc.
LS	Loudspeakers	Separately housed loudspeakers, intercommunication station
M	Microphones	Radio, telephone, throat, hand, etc.
MA	Magazines	Magnetic tape or wire, etc.
MD	Modulators	Device for varying amplitude, frequency or phase
ME	Meters, Portable	Multimeters, volt-ohm-milliammeters, vacuum tube voltmeters, power meters, etc.
MF	Magnets or Magnetic Field Generators	Magnetic tape or wire eraser, electro-magnet, permanent magnet, etc.

Table 3-3.—Table of Component Indicators—Continued.

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
MK	Miscellaneous Kits	Maintenance, modification, etc., except tool and crystal. (See CK, TK.)
ML	Meteorological Devices	Barometer, hygrometer, thermometer, scales, etc.
MT	Mountings	Mountings, racks, frames, stands, etc.
MX	Miscellaneous	Equipment not otherwise classified Do not use if better indicator is available
O	Oscillators	Master frequency, blocking, multivibrators, etc. (For test oscillators, see SG.)
OA	Operating Assemblies	Assembly of operating units not otherwise covered
OC	Oceanographic Devices	Bathythermographs, etc.
OS	Oscilloscope, Test	Test oscilloscopes for general test purposes
PD	Prime Drivers	Gasoline engines, electric motors, diesel motors, etc.
PF	Fittings, Pole	Cable hangar, clamp, protectors, etc.
PG	Pigeon Articles	Container, loft, vest, etc.
PH	Photographic Articles	Camera, projector, sensitometer, etc.
PP	Power Supplies	Nonrotating machine type such as vibrator pack, rectifier, thermoelectric, etc.
PT	Plotting Equipments	Except meteorological. Boards, maps, plotting table, etc.
PU	Power Equipments	Rotating power equipment except dynamotors. Motor-generator, etc.
R	Receivers	Receivers, all types except telephone
RC	Reels	Reel, cable. (See RL.)
RD	Recorder-Reproducers	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical, etc.
RE	Relay Assemblies	Electrical, electronic, etc.
RF	Radio Frequency Component	Composite component of R.F. circuits. Do not use if better indicator is available.
RG	Cables, R.F., Bulk	R.F. cable, waveguides, transmission lines, etc., without terminals

Table 3-3.—Table of Component Indicators—Continued.

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
RL	Reeling Machines	Mechanisms for dispensing and rewinding antenna or field wire, recording wire or tape, etc.
RO	Recorders	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical, etc.
RP	Reproducers	Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical, etc.
RR	Reflectors	Target, confusion, etc. Except antenna reflectors. (See AT.)
RT	Receiver and Transmitter	Radio and radar transceivers, composite transmitter and receiver, etc.
S	Shelters	House, tent, protective shelter, etc.
SA	Switching Devices	Manual, impact, motor driven, pressure operated, etc.
SB	Switchboards	Telephone, fire control, power, panel, etc.
SG	Generators, Signal	Test oscillators, noise generators, etc. (See O.)
SM	Simulators	Flight, aircraft, target, signal, etc.
SN	Synchronizers	Equipment to coordinate two or more functions
ST	Straps	Harness, straps, etc.
T	Transmitters	Transmitters, all types except telephone
TA	Telephone Apparatus	Miscellaneous telephone equipment
TD	Timing Devices	Mechanical and electronic timing devices, range device, multiplexes, electronic gates, etc.
TF	Transformers	Transformers when used as separate items
TG	Positioning Devices	Tilt and/or Train Assemblies
TH	Telegraph Apparatus	Miscellaneous telegraph apparatus
TK	Took Kits	Miscellaneous tool assemblies
TL	Tools	All types except line construction. (See LC.)
TN	Tuning Units	Receiver, transmitter, antenna, tuning units, etc.
TR	Transducers	Magnetic heads, phono pickups, sonar transducers, vibration pickups, etc. (See H, LS, and M.)
TS	Test items	Test and measuring equipment not otherwise included; boresighting and alignment equipment.

Table 3-3.—Table of Component Indicators—Continued.

Comp Ind.	Family Name	Examples of Use (Not to be construed as limiting the application of the component indicator)
TT	Teletypewriter and Facsimile Apparatus -----	Miscellaneous tape, teletype, facsimile equipment, etc.
TV	Tester, Tube ----------------------	Electronic tube tester
TW	Tapes and Recording Wires -------------	Recording tape and wire, splicing, electrical insulating tape, etc.
U	Connectors, Audio and Power -----------	Unions, plugs, sockets, adapters, etc.
UG	Connectors, R.F. -------------------	Unions, plugs, sockets, choke couplings, adapters, elbows, flanges, etc.
V	Vehicles -------------------------	Carts, dollies, trucks, trailers, etc.
VS	Signaling Equipment, Visual ------------	Flag sets, aerial panels, signal lamp equipment, etc.
WD	Cables, Two Conductor ---------------	Non-r.f. wire, cable and cordage in bulk. (See RG.)
WF	Cables, Four Conductor ---------------	Non-r.f. wire, cable and cordage in bulk. (See RG.)
WM	Cables, Multiple Conductor -------------	Non-r.f. wire, cable and cordage in bulk. (See RG.)
WS	Cables, Single Conductor --------------	Non-r.f. wire, cable and cordage in bulk. (See RG.)
WT	Cables, Three Conductor --------------	Non-r.f. wire, cable and cordage in bulk. (See RG.)
ZM	Impedance Measuring Devices -----------	Used for measuring Q, C, L, R or PF, etc.

For example, the receiver for the AN/SPS-2 would be identified (table 3-4 as follows):

Table 3-4.—Designation of Components.

Radar Receiver	R	7	/APS-2
Item name as prescribed	From table 3	The 7th receiver to which an "AN" designation has been assigned	The set it is used with or is a part of

Thus, the R-7/APS-2 is a receiver that is used with or is a part of airborne radar search set No. 2. Another receiver, such as the R-8/ARN-8, would be indicated by the tables as a receiver used with or as a part of airborne radio navigation set No. 8.

To identify a component that has been modified but which still retains the basic design and is interchangeable physically, electrically, and mechanically with the modified item, a modification letter is used, as on sets. Thus, the R-7A/APS-2 would be a modified version of the R-7/APS-2.

Components that are part of or used with two or more sets are identified in the usual way, except that after the slant bar, there will appear only those indicators that are appropriate and without a set model number. Thus, a modulator that is part of or used with the AN/APS-2 and the AN/APS-6 might be identified as MD-8/APS.

NAVY MODEL LETTER SYSTEM

The assignment of a particular model letter to Navy equipments depends on the primary function of the equipment, such as receiving, direction finding, etc. This system of assigning model letters is applicable to all radio, radar, and sonar equipments and once learned, makes easy the recognition and identification of all Navy equipments.

In this system, the first letter indicates the basic purpose of the equipment. These designations, which are listed in table 3-5, are followed by another letter of the alphabet to indicate the order in which designations are assigned. Thus, TA was the first transmitting equipment assigned, TB, the next, etc. When the alphabet was exhausted, triple letters were used—for example, TAA. The order of assignment was then indicated by a change in the third letter. Thus, the model letter assigned after TAA was TAB. When the alphabet was again exhausted, a third series of model letters was formed by changing the second letter to B—for example, TBA, TBB- - - - - - - - - TBS - - - - - - - - -.

Numbers following model letters indicate a modification of the equipment or the award of a new contract. To indicate a change in equipment after delivery has been made, lower case letters are assigned.

The Navy model letter system of equipment designation is no longer in primary use, now that the AN system has been instituted. There are, however, still some equipments with this type of designation in the naval establishment.

The Navy model letters used in sonar equipment are shown in table 3-6. The first letter indicates the general use of the equipment. The second letter of the "Q" series equipment designates the type of projector used, as indicated in table 3-6.

Table 3-5.—Navy Model Letters.

Model Letters	Primary Function of the Equipment
A	Airborne—used as a prefix to indicate airborne installation as: AR series —airborne radio receiving, etc.
B	IFF
CX	Commercial experimental
D	Radio direction finding
E	Emergency power
FS	Frequency-shift keying
G	Formerly aircraft transmitting (now superseded by "A" series)
J	Sonar listening (receiving)
K	Sonar transmitting
L	Precision calibrating
M	Combined radio transmitting and receiving
MARK	Fire-control radar
N	Sonar navigational aids including echo sounding
O	Measuring and operator training
P	Automatic transmiting and receiving
Q	Sonar ranging
R	Radio receiving
S	Search radar
T	Radio transmitting (includes combination transmitting and receiving)
U	Remote control (includes automatic keyers)
V	Radar repeaters
W	Combined sonar ranging and sounding
X	Naval experimental
Y	Navigational and landing aids
Z	Navigational and landing aids (airborne)—superseded by model Y series

WIRING DIAGRAMS

Wiring diagrams are shorthand records (with symbols) which represent electronic equipments and their terminals. Primarily, these diagrams indicate which terminals are interconnected with wires.

The uses, arrangements, and interpretation of symbols are found in MIL-STD-15-1, entitled Military Standards of Graphical Symbols for Electrical and Electronic Diagrams, Part 1. Information on this subject is given also in

Table 3-6.—Navy Model Letters Used In Sonar Equipment.

Model Letters	Type of Projector Used
QA	Quartz steel
QB	Rochelle salt
QC	Magnetostriction
QD	Depth determining (not echo sounding)
QG	Magnetostriction—split-lobe type
QH	Scanning sonar

Blueprint Reading and Sketching, NavPers 10077-B.

Not only do symbols and usages change from time to time but new ones are introduced. Accordingly, it is well to check current publications (diagrams versus standard symbols).

TERMINAL DESIGNATIONS

The following information condensed from Dictionary of Standard Terminal Designations for Electronic Equipment, NavShips 900,186, will be helpful to ETs.

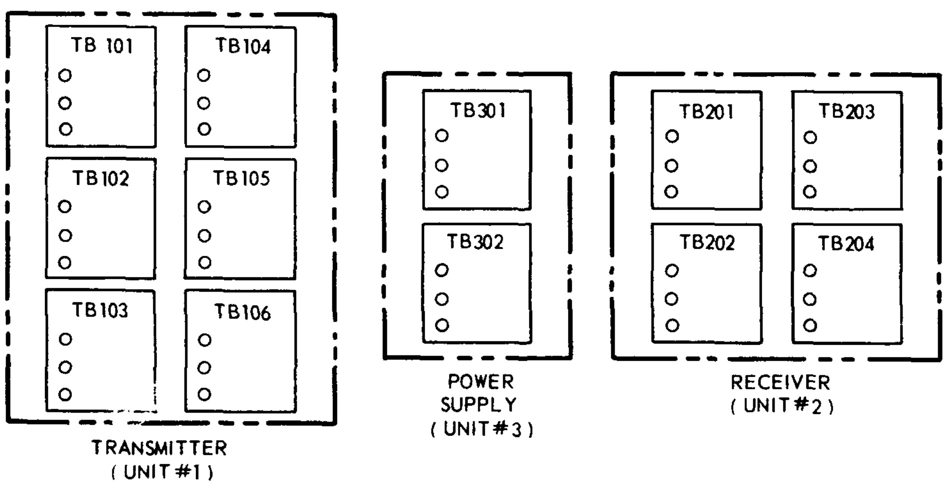
TERMINAL BOARDS

Terminal boards are marked with a three-or four-digit number preceded by "TB." This marking is easily identified by the technician. The first one or two digits of the "TB" number represent the unit number in an equipment. This number is assigned by the manufacturer in a logical order. The last two digits represent the terminal board number in a unit, starting with 01, 02, 03, - - - - - - - 11, 12, 13, etc. Thus, a terminal board marked TB1003 indicates the third terminal board in the 10th unit of an equipment.

As an example, an equipment might be composed of a transmitter, a receiver, and a power supply, with the transmitter having six external terminal boards, the receiver four external terminal boards, and the power supply two external terminal boards. The manufacturer will then assign numbers to the units—perhaps 1 for the transmitter, 2 for the receiver, and 3 for the power supply. Figure 3-1 shows how the terminal boards would then be marked.

TERMINAL MARKING

The marking of terminals on terminal boards indicates a specific function for the following circuits: (1) common primary power circuits, (2) ground terminals, (3) common servo and synchro circuits, (4) video circuits, (5) trigger circuits, and (6) audio circuits. The breakdown of these categories into specific functions, with



70.1

Figure 3-1.—Terminal board marking.

the terminal designation of each, is listed in NavShips 900,186. These are RIGIDLY ASSIGNED DESIGNATIONS.

Terminals whose functions do not fall under the categories listed are assigned designations by the equipment manufacturer in accordance with NavShips 900,186. These are MANUFACTURER-ASSIGNED DESIGNATIONS.

Only those terminals that will be connected together externally will have exactly the same designation within any given equipment.

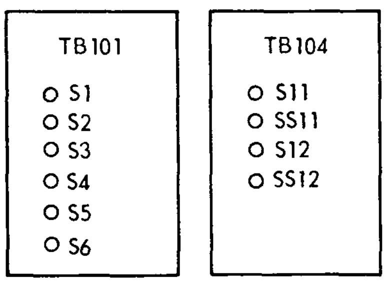
RIGIDLY ASSIGNED DESIGNATIONS.—Functional designations for circuits in the previously listed categories may be recognized by a one- or two-digit number preceded by a single or double letter (I and O are not used) such as S1, S2, S11, SS11, etc. These designations are stamped or engraved on the terminal board beside each terminal, as shown in figure 3-2.

If the same function appears more than one time in an equipment it is distinguished by the addition of a letter or letters after the designation, beginning with "A," as shown in figure 3-3.

If more than 25 sets of terminals have the same function in an equipment, the letter following is then doubled (for example, S1AA). If these letters are used up, combinations of letters (for example, S1AB) are used.

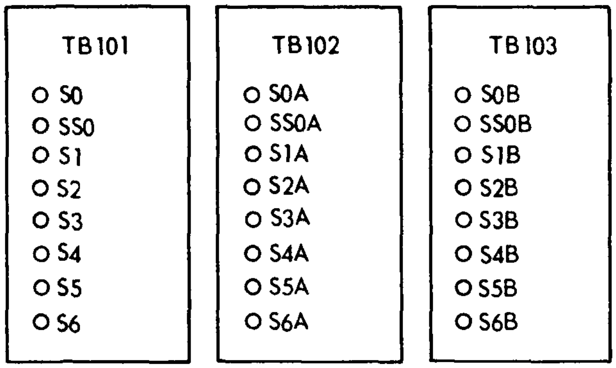
MANUFACTURER - ASSIGNED DESIGNATIONS.—These designations begin with a number rather than a letter, as opposed to rigidly assigned designations.

When a "nonrigidly assigned" function is brought out to a terminal, the manufacturer assigns 1A to the first such terminal and also 1A to the terminal that is to be tied to this point. The designation, 1A, does not appear again unless



70.2

Figure 3-2.—Designations appearing beside terminals.



70.3

Figure 3-3.—Designating terminals of the same function.

it is to be tied directly to either of the terminals already marked.

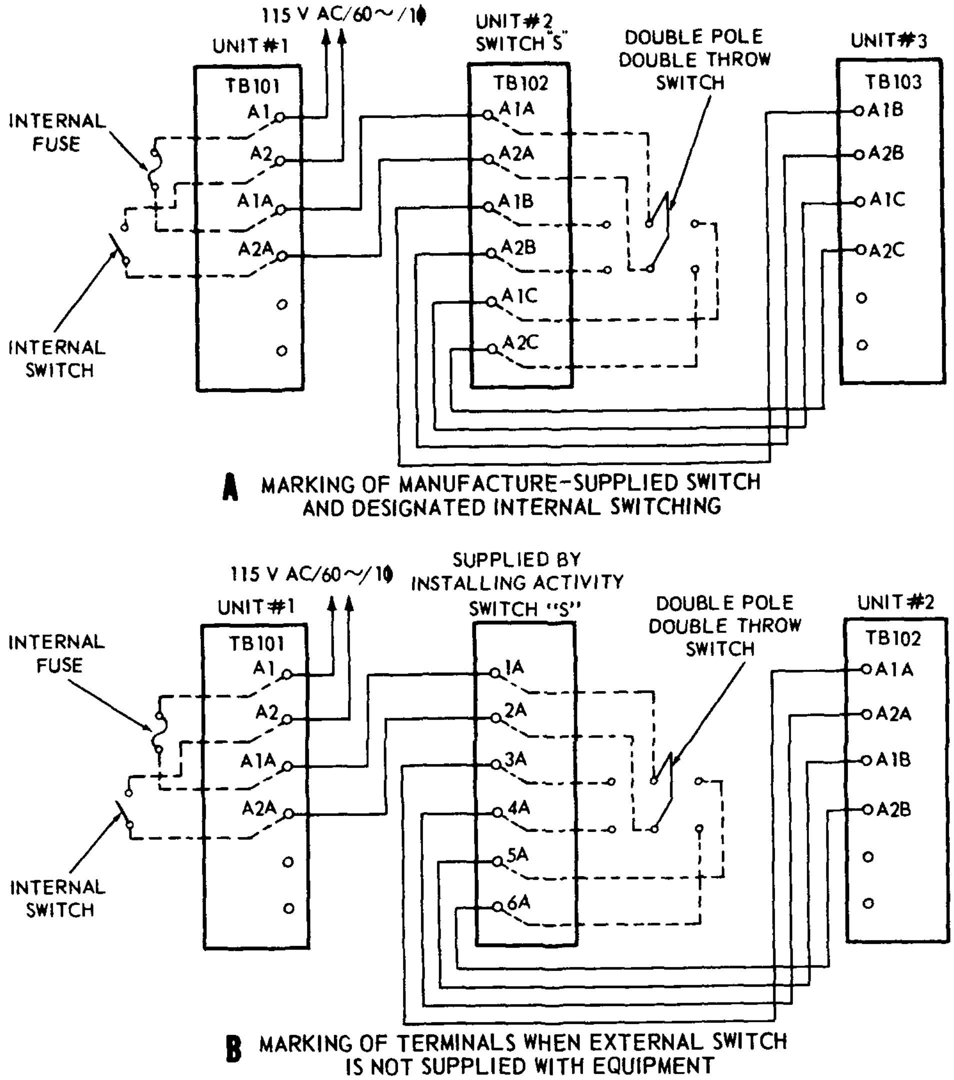
As more manufacturer-assigned designations are used, 2A, 3A -------- 99A are used; then 1B, 2B ---------- 99B and up to 1Z, 2Z--------- 99Z (omitting I and O) are used. If additional numbers are needed, the letters are doubled or combinations of two letters are used.

SWITCHING AND FUSING DESIGNATIONS

Possible switching designations are illustrated in figure 3-4. If switch "S" is designed to be used with the equipment, the markings would be as shown in part A. If switch "S" is Government supplied, the terminals would be marked differently, perhaps as 1A through 6A, as illustrated in part B.

ORDER OF TERMINALS ON TERMINAL BOARD

All circuits of a given function on a terminal board are grouped and arranged in a particular order. This grouping applies for rigidly assigned and manufacturer-assigned designations. Primary power circuits, unless connected to a separate fuse block instead of a terminal board proper, are the first connections on a terminal board. Synchro/servo circuits are arranged in sequence of reference or excitation. No particular position or area of any terminal board is reversed for a synchro function, but a logical order is illustrated in figure 3-5.



70.4

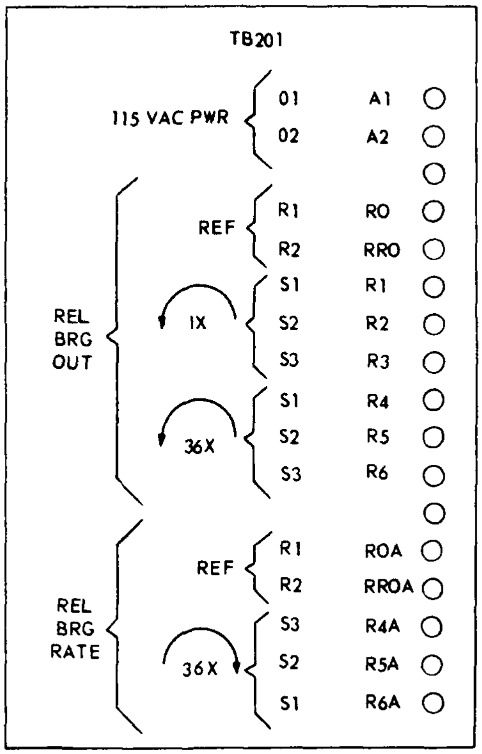
Figure 3-4.—Possible switching and fusing designations.

All circuits of each video, trigger, or audio function will appear in sequence, each with its associated ground where such ground is unique to that particular function.

CONDUCTOR MARKING

On the conductor lead, at the end near the point of connection to a terminal post, spaghetti sleeving is used as a marking material and insulator. The sleeving is engraved with indelible ink, or branded with identifying numbers and letters by a varitype machine, and slid over the conductor.

The order of marking is such that the first appearing set of numbers and letters reading from left to right will be the designation corresponding to the terminal to which that end of the



70.5

Figure 3-5.—Functional grouping of terminals, showing proper order within groups.

wire is connected. Following this, there is a dash and then the number (without the "TB") of the terminal board to which the other end of the conductor is attached. There is another dash and then the designation of the particular terminal to which the other end of the wire is connected. For example, assume that a conductor of a cable runs between units Nos. 1 and 2 of an equipment. The terminal boards are TB101 and TB201, and the terminals are designated A1 on both terminal boards. Figure 3-6A shows the order and method of marking spaghetti sleeving under these conditions. Figure 3-6B illustrates conductor marking between unlike terminals.

LEAD DESIGNATIONS ON SCHEMATIC DIAGRAMS

Navy receivers like the AN/SRR 11, 12, and 13 series are compartmentalized into assemblies and subassemblies. All circuits to an assembly (with certain exceptions) are disconnected when the assembly is lifted from the chassis and connected when the assembly is fitted into position. The individual subassemblies consist of a subminiature electron tube and the circuit for one stage. The subassembly plugs into an appropriate socket of the assembly. The circuits terminate in connector receptacles, as illustrated in figure 3-7. Each terminal is identified by letter. Where connecting leads merge into a single cable the identity of the individual circuits is maintained by letter-number designation. For example, the Out-Hi lead to terminal L of J126 is connected through the matching connector receptacle plug-jack arrangement to L of J253. The outgoing lead is marked J254-B. This lead is marked at terminal B of J254 as J253-L. Thus the outgoing lead is identified with the letter-number designation of the connector in which that lead terminates J254-B. At this termination the lead is identified with the letter-number designation of the connector in which that lead originates (J253-L). This system facilitates servicing and troubleshooting. Simplified schematics can easily be developed from this method of designating leads.

DESIGNATIONS FOR ATTENUATOR NETWORKS

Attenuator networks are illustrated in figure 3-8. They are used to attenuate signal voltages, and in many cases to effect an impedance match as well. The name of the network appears just above the schematic diagrams in the figure.

A BALANCED circuit is one in which both lines are at equal potential above ground. An UNBALANCED circuit is one in which one line is at ground potential.

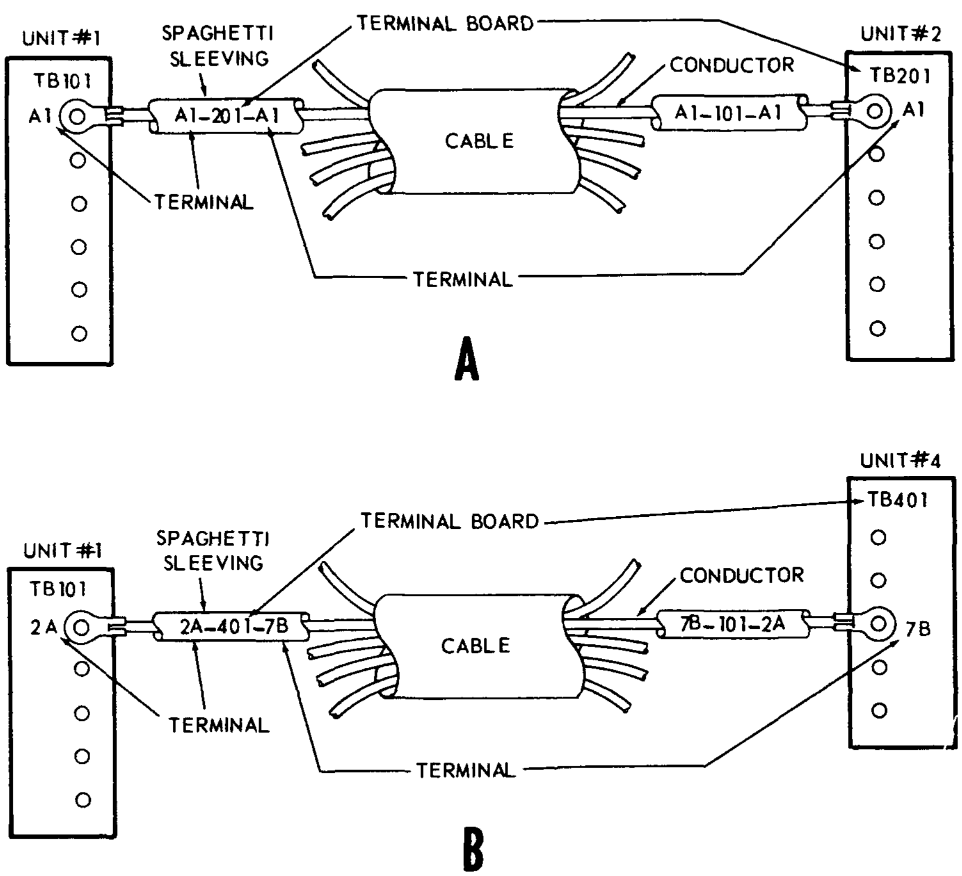
WIRING COLOR CODE FOR ELECTRONIC EQUIPMENT

To aid in testing and locating faults in electronic equipment, and in subsequent repair, the Department of Defense has set up a military standard (MIL-STD-122), which establishes a uniform wiring color code for all military electronic equipment. This standard is used in manufacturing and should also be followed in maintenance practices when circuit changes and part replacements are involved.

The standard colors used in chassis wiring are listed in table 3-7.

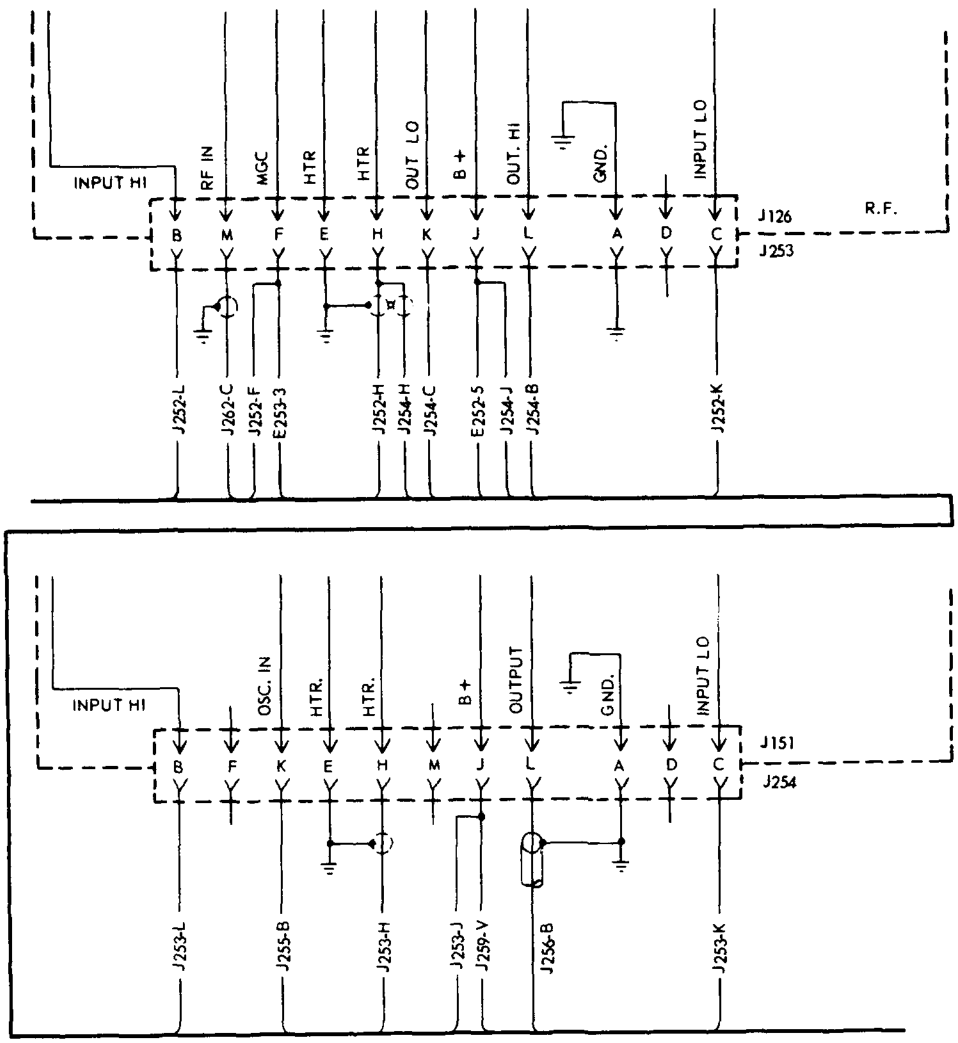
Table 3-7.—Wiring Color Code For Electronic Equipment.

Circuit	Color
Grounds, grounded elements, and returns	Black
Heaters or filaments, off ground	Brown
Power supply, B plus	Red
Screen grids	Orange
Cathodes	Yellow
Control grids	Green
Plates	Blue
Power supply, minus	Violet (purple)
A-c power lines	Gray
Miscellaneous, above or below ground returns, AVC, etc.	White



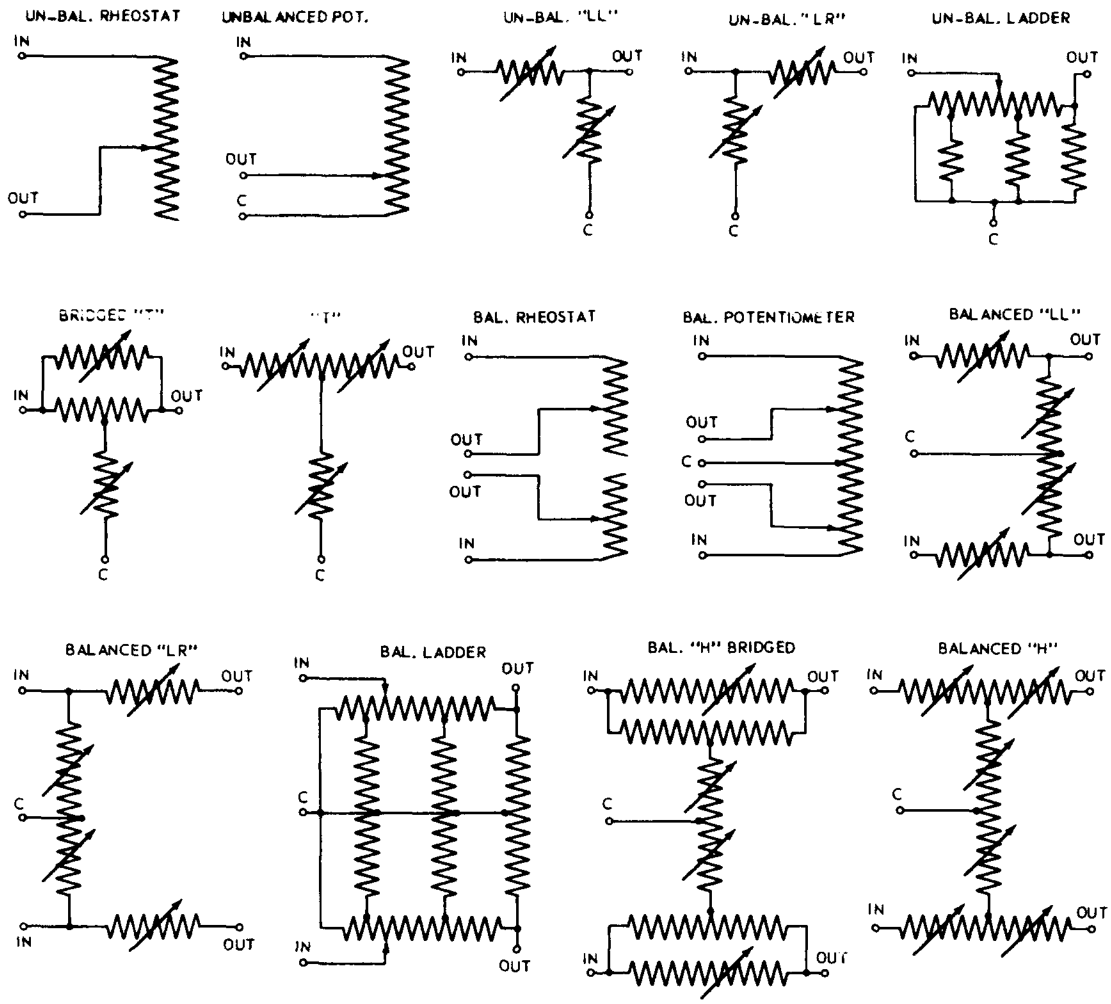
70.6

Figure 3-6.—Designating conductor marking between terminals.



70.7

Figure 3-7.—Illustration of lead designations on schematic diagrams.



70.8

Figure 3-8.—Attenuator networks.

CHAPTER 4

TECHNICAL PUBLICATIONS AND RECORDS

In addition to the training courses mentioned previously, there are various technical publications with which the ET must become familiar. These publications will be discussed in this chapter. Records concerning electronic equipments that you will either be required to maintain or have knowledge of are also discussed.

TECHNICAL PUBLICATIONS

Electronic technical publications include various handbooks, bulletins, and manuals published and distributed by the Bureau of Ships, and manufacturers' technical manuals. The Requisitioning Guide and Index of Forms and Publications, NavSandA-2002 furnishes a complete list of BuShips technical publications along with instructions for ordering copies.

HANDBOOKS AND BULLETINS

Handbooks present information about a particular field of work, or about a particular type of equipment, in a practical form. One such publication is the Handbook of Test Methods and Practices, NavShips 91828A (or the latest revision); others are the Handbook of Naval Shore Station Electronics Criteria, NavShips 92675, and the Electronic Test Equipment Handbook, NavShips 900-155.

One bulletin of great importance to the ET is the Electronics Information Bulletin (EIB), NavShips 900-022A, published biweekly for naval electronics activities. A complete file of these bulletins should be maintained.

This bulletin lists field changes and corrections that must be made in instruction books and other publications that are used in the maintenance of electronic equipment. It also lists electronics publications that become available, and gives valuable suggestions, from case histories, for servicing electronic equipment.

Although not called a bulletin as such, the Electronics Installation and Maintenance Book (EIMB), NavShips 900-000, includes essentially the summarized (permanent) information formerly contained in various service bulletins, such as the RMB, CEMB, EIB, and SB. For convenience, the EIMB comprises several volumes, covering general information of an electronics nature in each major electronics field. The present name of EIMB was changed from EMB.

At present the EIMB is being completely revised. This revision will be carried out in several steps, and includes incorporating into the EIMB the following NavShips publications; Reporting Electronic Equipment Installation, 900-135(B); Handbook of Test Methods and Practices Manual, 91828(A); Installation Practices Manual, 900-171; Antenna Details, 900-121(A); Basic Communication Systems Interconnection Wiring Plans, 900-176, Volume 1; Shipboard Radar and IFF System Design Plans, 900-176, Volume 2; and Shipboard Electronics Equipment Installation Plans, 900-153(A).

The Handbook of Electronic Circuits, NavShips 900-000.102, currently under preparation will include most conventional electronic circuits (oscillators, detectors, amplifiers, etc.) and their theory of operation. The new equipment technical manuals will not duplicate these explanations but will simply refer to them. In this way it is planned to reduce the amount of material in the theory portions of technical manuals associated with electronic equipments.

INSTALLATION AND MAINTENANCE MANUALS

Installation and maintenance manuals contain information concerning the installation, operation and maintenance of specific electronic equipments. This information is included in instruction books or technical manuals issued by

the manufacturers, and various BuShips publications.

Manufacturers Technical Manuals

Manufacturers technical manuals are prepared according to military specification MIL-M-15071 E, of 15 April 1962. This specification establishes four types of manuals and provides specific instructions for preparing each type. The types of manuals are: type 1, electrical and mechanical; type 2, electronic and special equipment; type 2a, experimental equipment; and type 3, systems. You will be concerned with the type 2 manual. The material in this manual is arranged in six sections as follows:

Section 1. General information—This section provides a functional description of the equipment and includes the capabilities, limitations, and relationship of the units.

Section 2. Installation—This section includes such information as primary power data, initial adjustment, inspection procedures, unpacking and handling, and installation requirements.

Section 3. Operation—This section includes routine and emergency operating instructions, safety precautions, and operating limits.

Section 4. Troubleshooting—Included in this section are all diagrams and information required by the ET to troubleshoot the equipment. This section includes the six-step method of troubleshooting discussed in chapter 13 of this training course.

Section 5. Maintenance—This section provides information and instructions necessary for maintaining and repairing the equipment. All preventive maintenance procedures and test inspections are included in this section if they are not included in a separate maintenance standards book.

Section 6. Parts list—This section includes a list of manufacturers, and data concerning maintenance parts for the equipment.

In addition to the material in sections 1 through 6, the manual contains front matter and an index.

Electronics Installation Practices Manual (EIPM), NavShips 900-171

The Electronic Installation Practices Manual (EIPM), NavShips 900-171, is composed of many separately bound chapters. This manual provides information on standard methods of installation of electronic equipments and systems.

Shipboard Antenna Details, (NavShips 900-121)

Shipboard Antenna Details, NavShips 900-121, is composed of several separately bound chapters, and is intended to serve as a source of information for those concerned with installing ship antennas.

Bureau of Ships Technical Manual, (NavShips 250-000)

The Bureau of Ships Technical Manual is an authoritative technical publication issued for the information and guidance of naval personnel, afloat and ashore, responsible for or engaged in the operation, maintenance, and repair of machinery, apparatus, and equipment under cognizance of the Bureau of Ships.

Chapter 67 of the manual is titled Electronics, and is required reading for electronics personnel. Additional chapters of the technical manual and various other publications are listed in chapter 67. These are informative and of value to electronics personnel.

MISCELLANEOUS PUBLICATIONS

The Bureau of Ships Journal, NavShips 250-200, is published monthly, and frequently carries articles of interest to Electronics Technicians. Other publications that will be helpful to you are, U.S. Navy Synchros, OP 1303; Radio Frequency Transmission Lines, NavShips 900-008; and Security Classifications of Electronic Equipment, NavShips 93140.

CORRECTIONS TO TECHNICAL PUBLICATIONS

It is important that all technical publications be kept up to date. You will be concerned with making corrections to the electronics technical publications. The corrections are distributed by BuShips as change sheets, as required.

These change sheets are detailed regarding the kind of entries (temporary or permanent) and their purposes. Many changes involve field changes covering specific serial numbers; when that condition applies, the entry is made only upon completion of the job. Be certain that holders of equipment accompanied by technical manuals do not make this correction in the manual until accomplishment of the field change.

Make pen-and-ink corrections in all entries and in all locations as specified. Make them clear and legible. Remember, such entries are permanent; therefore they must be readable.

Following the initial entry, review the change sheet instructions to be certain every requirement is fulfilled.

RECORDS

Each activity engaged in the operation of electronic equipment is required to maintain cards for recording the results of inspections of equipments, and records of any tests, repairs, and field changes made. The material history, composed of cards filed in looseleaf binders, supersedes the machinery history and hull repair books formerly required aboard ship. Such cards as the Machinery History Card, NavShips 527, Material History Card-Electrical, NavShips 527A, Electronic Equipment History Card, NavShips 536, and Hull History Card, NavShips 539, form the basis of the ship's material history. (ETs are responsible for NavShips 536 only.) These cards provide a comprehensive record of the items concerned. They are kept up to date and available for inspection at all times and are integrated into preventive maintenance programs such as the Current Ships Maintenance Project (CSMP).

The maintenance history cards that the ET3 should be especially familiar with are described in the following paragraphs.

ELECTRONIC EQUIPMENT HISTORY (CARD, NAVSHIPS 536)

This card is the basic maintenance history card for electronic equipment. It provides for recording failures and other information pertaining to electronic equipments. A separate card is filled in for each equipment and major unit on board. If additional cards are required for an equipment they are added behind the original card in the binder. All cards for a particular equipment are transferred with the equipment when it is removed from the ship.

The heading of the card should be typed, but entries on the body of the card may be either typed or written in ink or indelible pencil. The filling instructions should be followed closely in filling in the form, a sample of which is shown in figure 4-1.

Equipment Model Designation: All letters and numbers should be included to indicate the specific model. For instance, AN/GRC-27 should not be entered as AN/GRC or GRC-27.

Equipment Serial Number: This number is taken from the equipment nameplate. If an overall equipment number is not available, the serial number of the major unit is listed for the entire equipment. When it is definitely established that an item does not bear a serial number, an asterisk (*) is entered in this space. Cards are made up for each unit of an electronic equipment and placed together in the folder. For example, on the AN/SPA-33 the Azimuth-Range Indicator is listed as IP-442/SPA-33, the Power Transformer as TF-129A/SP, and the Power Supply as PP-560C/SP.

Card Number: The number in this space is "1" for each card in the original file. As additional cards for a specific equipment are filed, they are numbered consecutively.

Name of Contractor: Enter here the name of the contractor in full as given on the unit nameplate or in the technical manual.

Contract Number: The complete contract number includes all letters and numbers as given on the equipment or unit nameplate.

Date Installed: This space refers to the date the equipment or unit was installed. If the installation required several days, the date of completion is the date entered.

Installing Activity: This space is for the name of the activity that actually installed the equipment.

Box Number and Location: On ships with integrated parts system this space may be left blank, unless for some reason the equipment is not included in the system. Otherwise, the appropriate box number (and location) is entered in this space.

Instruction Book on Board: Check this space only when the final instruction book is received. If only the preliminary book is on board, this space should not be checked. EIB carries notices of the availability of final instruction books.

Date: Enter here the date of failure, field change, or other work involving maintenance or repair.

Nature of Trouble: External evidence of the equipment trouble is entered in this column and should be described in detail. Whenever a field change is made, the field change number and title are also shown in this column in addition to the entry required on the Record of Field Changes, NavShips 537.

Cause of Failure: This column is most important. Describe how the trouble was traced and what corrective measures were taken. Give detailed information. Note peculiarities and weaknesses. The clearer the information in this column, the more valuable it is to the ship, the Bureau of Ships, and the manufacturer. The information in this column, and that reported on the Defense Department Electronics Failure Report, DD787, assists in the production of better and more reliable equipment.

Some activities may wish to record in this column such information as the name and rate of the person actually doing or supervising the work, the man-hours consumed, and the signature of the Division Officer. Such entries are optional.

Name of Part: List here the names of the parts involved in the failure.

Circuit Symbol: Record here the symbol designations of the parts that failed, as shown in the instruction book.

Navy Stock Number: This space should be relabeled "Federal Stock number" or "FSN". If the federal stock number is unavailable, list the manufacturer's part number, or other identifying numbers.

Life Hours: Enter here the estimated life of the part. To obtain this figure, use the machinery history cards, readings of elapsed time meters that total the operating time of the part, or any other available data.

Date DD787 Mailed: (This column was formerly headed "Date NavShips 383 Mailed.") Record the mailing date if DD787 was mailed to the Bureau of Ships.

CURRENT SHIP'S MAINTENANCE PROJECT

The purpose of the current ship's maintenance project (CSMP) is to provide a current record of maintenance, modifications, and repairs to be scheduled and finally accomplished

ELECTRONIC EQUIPMENT HISTORY CARD

Equipment Model Designation	Equip. Ser. No.	Name of Unit and Type No.	Card No.
AN/GRC-27A	1204	RECEIVER R-278B/GR	1

Name of Contractor	Contract No.	Date Installed	Serial No. of Unit
NATIONAL COMPANY, INC.	NXsr-55624	5 JULY 1961	1204

Location: RADIO ROOM C-201-L	Installing Activity: NNSY
Spare Parts — Box No. and Location: 2 CIC	Instr. Bk. On Board (Check): ☒

Date	Nature of Trouble (Or F. C. No. and Title)	Cause of Failure Brief Description of Work Done	Name of Part	Circuit Symbol	Navy Stock No. FSN	Life Hours	Date NavShips 383 Mailed
10/6/62	NO SIGNALS	OPEN FILAMENT REPLACED	TUBE	V201	W5960-615	300	10/16/62
		V201			5528		
12/2/62	F.C. # 4						
	MODIFICATION TO						
	IMPROVE STABILITY						
	OF I F AMPLIFIER						

1.2

Figure 4-1.—Electronic equipment history card, NavShips 536

by ship's personnel or by repair activities afloat or ashore.

The CSMP consists of the following three cards:

NavShips 529—Repair Record Card (blue)
NavShips 530—Alteration Record Card (pink)
NavShips 537—Record of Field Changes (white)

As a repair is required or an alteration is authorized, the work is scheduled by filling out an applicable CSMP card and placing it so the top line of the card is in view alongside the proper history card, NavShips 536. These CSMP cards are of a distinctive color, which facilitates the indication of outstanding work when the history is examined.

When the item of work has been completed, entries are made in two places. One entry of completion is made on the CSMP card, and the other entry is made on the history card, NavShips 536.

Upon completion of work, the Record of Field Changes, NavShips 537, remains with its NavShips 536. However, cards NavShips 529 and 530 are removed from their position adjacent to the history card and filed in a "completed work" section of the CSMP.

Repair Record Card, NavShips 529, and Alteration Record Card, NavShips 530

The blue repair and pink alteration cards are identical as to block descriptions, therefore, the description of the entries apply to both cards. Their distinctive colors aid in distinguishing repair from alteration projects.

Repair record cards and alteration record cards are retained for a period of 2 years, following which these cards may be destroyed at the discretion of the commanding officer. When ships are decommissioned or placed out of service during this period, the cards are retained onboard.

If the equipment is transferred, these cards are transferred with it.

Record of Field Changes, NavShips 537

Field changes scheduled and later made to any portion of an electronic equipment are recorded on this card, which is filed in the binder adjacent to the history card for the equipment to which the change is applicable. Completion of field change information is also entered on NavShips 536.

This record is of paramount importance. Without modifications, an equipment may be dangerously out of date and subject to numerous serious difficulties. Without a record of field changes it is difficult to determine what modifications, if any, have been made. The information recorded on these cards is essential for routine maintenance, for troubleshooting, and for ordering maintenance parts for the improved equipment.

Figure 4-2 shows the Record of Field Changes Card, NavShips 537. The spaces for equipment model designation, serial number, date installed, and card number are filled in by typing or writing with ink or indelible pencil. The official name or Navy type number (or other official identification) of each component affected by a field change is shown parenthetically after the title of a change.

The columns headed "No.," "Title of Field Changes," and "Authority for Change" are completed in numerical order for all changes affecting a specific equipment. Field changes that affect certain equipments are made known in the Electronics Installation and Maintenance Book (EIMB). Enter applicable extracts from EIMB on the NavShips 537 card to indicate exactly its EIMB source and language. The Electronics Information Bulletin (EIB) lists field changes and is also an authority for making such changes.

Do not use obsolete entries on NavShips 537.

Approximately once a year, the Bureau of Ships determines which EIBs become obsolete because their items are published elsewhere in permanent form (in EIMB and IB publications). For example, the initial 200 copies of EIB, were named Repair Information Bulletin (RIB) and these are canceled (as summarized in EIB 476) along with EIBs from serial numbers 1 through 380. Until further notice, serial numbers above 380 shall be considered authoritative and directive in nature for announcing field changes that are active.

Many field changes are issued directly from the Bureau to a ship. Whatever its source, list the authority for such changes in the column provided for it on NavShips 537.

EQUIPMENT FAILURE AND PERFORMANCE RECORDS

The Bureau of Ships must receive accurate reports from the fleet concerning equipment performance and failures, in order to evaluate it's reliability and maintainability. Reports are

also necessary to determine whether new equipments are meeting their design capabilities and operational requirements.

Reported failures are tabulated on IBM cards, and regular summaries are made to show at a glance the number and types of failures of any part of any equipment.

The importance of reporting failures and their causes cannot be too highly stressed, particularly if failures occur under actual operating conditions. The reports are to be filled in completely and in conformity with the instructions accompanying the card. Many reports received by the Bureau are valueless because they do not give the essential information required by the form or because the information given is incomplete. When indicating the model or type of equipment, include all significant nomenclature, letters, and digits.

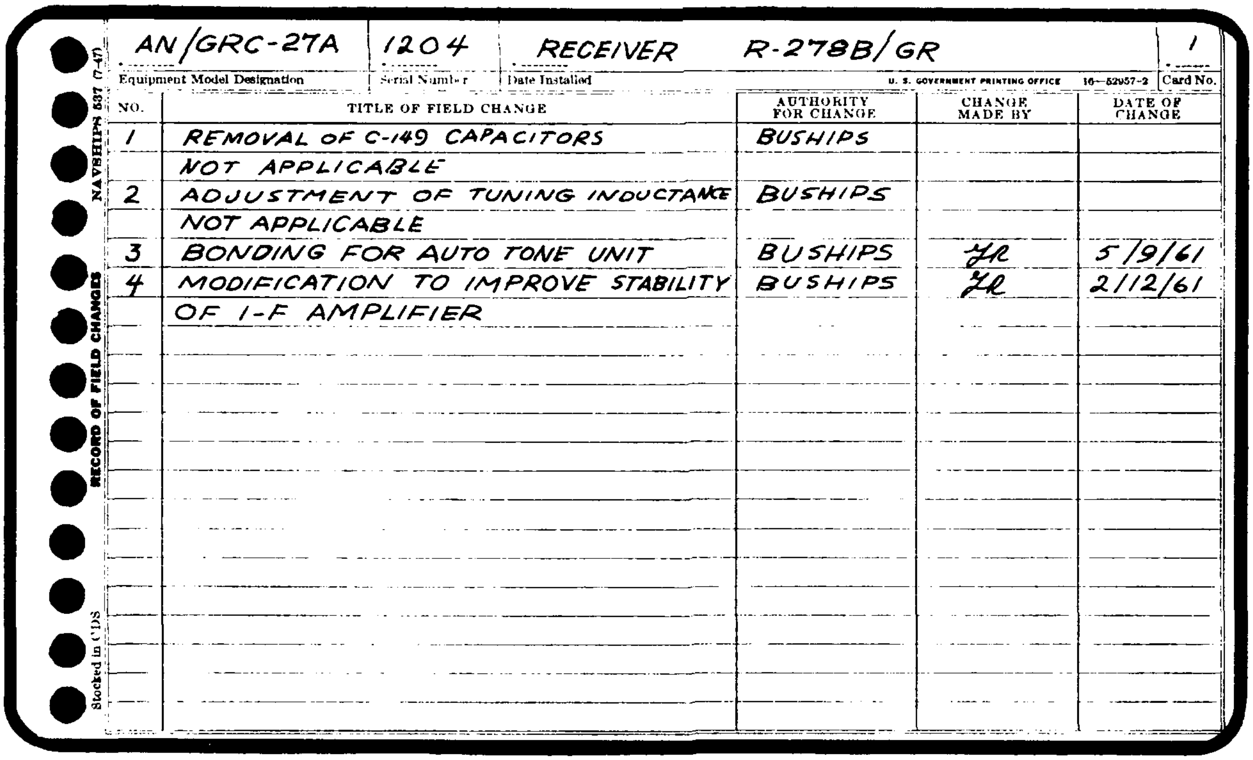
Electronic Equipment Failure/Replacement Report, DD-787

Failures to electronic equipment are reported according to BuShips Instruction 10550.73. The Department of Defense has developed the new Electronics Failure Report Form, DD-787 (fig. 4-3), which replaces the corresponding failure report forms in use by each of the military departments. For naval activities, it supersedes an older DD-787.

One major distinction between the old and the new form DD787 is that the new form is an equipment/part failure report, while the old form was only a parts failure report.

The new report (fig. 4-3) and the Electronic Equipment Operational Time Log (discussed later) are submitted only upon failure of specified equipments. The initial list of specified equipments is shown in the previously referenced BuShips Instruction 10550.73. Additions and deletions will appear in the EIB, which must be checked in each biweekly issue because listed additions will change your reporting requirements.

The new DD-787 failure/replacement form is arranged so that all failure information relating to one equipment can be entered on the form. This should simplify the maintenance paperwork



NAVSHIPS 537 (7-47) RECORD OF FIELD CHANGES

Equipment Model Designation	Serial Number	Date Installed		Card No.
AN/GRC-27A	1204	RECEIVER	R-278B/GR	1

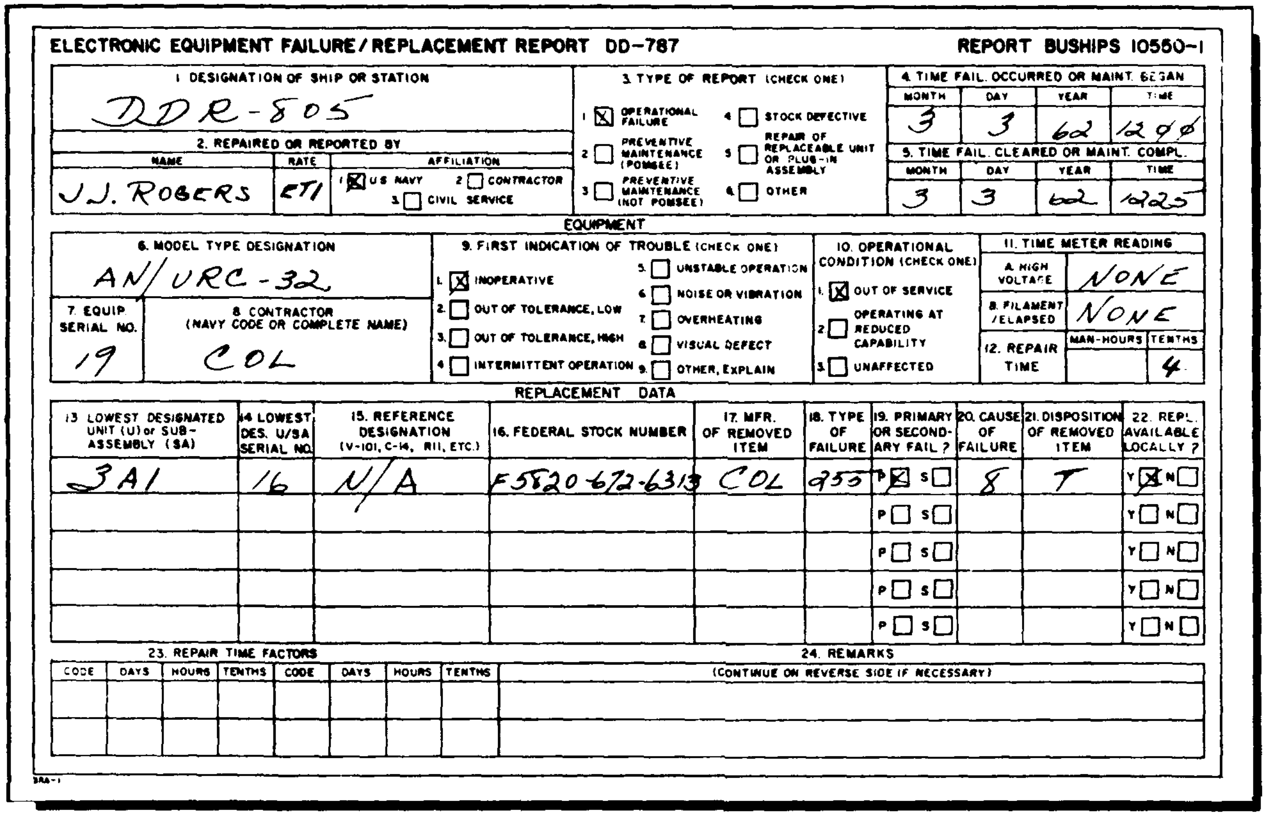
U. S. GOVERNMENT PRINTING OFFICE 16—52057-2

NO.	TITLE OF FIELD CHANGE	AUTHORITY FOR CHANGE	CHANGE MADE BY	DATE OF CHANGE
1	REMOVAL OF C-149 CAPACITORS	BUSHIPS		
	NOT APPLICABLE			
2	ADJUSTMENT OF TUNING INDUCTANCE	BUSHIPS		
	NOT APPLICABLE			
3	BONDING FOR AUTO TONE UNIT	BUSHIPS	[illegible]	5/9/61
4	MODIFICATION TO IMPROVE STABILITY	BUSHIPS	[illegible]	2/12/61
	OF I-F AMPLIFIER			

Stocked in CDS

1.4

Figure 4-2.—Record of field changes, NavShips 537.



ELECTRONIC EQUIPMENT FAILURE/REPLACEMENT REPORT DD-787 REPORT BUSHIPS 10550-1

1. DESIGNATION OF SHIP OR STATION: DDR-805

2. REPAIRED OR REPORTED BY

NAME	RATE	AFFILIATION
J.J. ROBERS	ET1	1 [X] US NAVY 2 [ ] CONTRACTOR 3 [ ] CIVIL SERVICE

3. TYPE OF REPORT (CHECK ONE)
1 [X] OPERATIONAL FAILURE
2 [ ] PREVENTIVE MAINTENANCE (POMSEE)
3 [ ] PREVENTIVE MAINTENANCE (NOT POMSEE)
4 [ ] STOCK DEFECTIVE
5 [ ] REPAIR OF REPLACEABLE UNIT OR PLUG-IN ASSEMBLY
6 [ ] OTHER

	MONTH	DAY	YEAR	TIME
4. TIME FAIL. OCCURRED OR MAINT. BEGAN	3	3	62	1200
5. TIME FAIL. CLEARED OR MAINT. COMPL.	3	3	62	1225

EQUIPMENT

6. MODEL TYPE DESIGNATION: AN/URC-32
7. EQUIP. SERIAL NO.: 19
8. CONTRACTOR (NAVY CODE OR COMPLETE NAME): COL

9. FIRST INDICATION OF TROUBLE (CHECK ONE)
1. [X] INOPERATIVE
2. [ ] OUT OF TOLERANCE, LOW
3. [ ] OUT OF TOLERANCE, HIGH
4. [ ] INTERMITTENT OPERATION
5. [ ] UNSTABLE OPERATION
6. [ ] NOISE OR VIBRATION
7. [ ] OVERHEATING
8. [ ] VISUAL DEFECT
9. [ ] OTHER, EXPLAIN

10. OPERATIONAL CONDITION (CHECK ONE)
1. [X] OUT OF SERVICE
2. [ ] OPERATING AT REDUCED CAPABILITY
3. [ ] UNAFFECTED

11. TIME METER READING
A. HIGH VOLTAGE: NONE
B. FILAMENT/ELAPSED: NONE

12. REPAIR TIME: MAN-HOURS: ; TENTHS: 4

REPLACEMENT DATA

13. LOWEST DESIGNATED UNIT (U) or SUB-ASSEMBLY (SA)	14. LOWEST DES. U/SA SERIAL NO.	15. REFERENCE DESIGNATION (V-101, C-14, R11, ETC.)	16. FEDERAL STOCK NUMBER	17. MFR. OF REMOVED ITEM	18. TYPE OF FAILURE	19. PRIMARY OR SECONDARY FAIL.?	20. CAUSE OF FAILURE	21. DISPOSITION OF REMOVED ITEM	22. REPL. AVAILABLE LOCALLY?
3A1	16	N/A	F5820-672-6313	COL	955	P [X] S [ ]	8	T	Y [X] N [ ]
						P [ ] S [ ]			Y [ ] N [ ]
						P [ ] S [ ]			Y [ ] N [ ]
						P [ ] S [ ]			Y [ ] N [ ]
						P [ ] S [ ]			Y [ ] N [ ]

23. REPAIR TIME FACTORS

CODE	DAYS	HOURS	TENTHS	CODE	DAYS	HOURS	TENTHS

24. REMARKS (CONTINUE ON REVERSE SIDE IF NECESSARY)

3RA-1

15.2

Figure 4-3.—Electronic equipment failure/replacement report, DD-787.

which resulted from earlier (obsolete) requirements of listing only a single part on a single card. This new form, combined with the Operational Time Log, NavShips 4855, provides the necessary data for accurately showing: (1) mean-time-between failures, (2) mean-time-to-repair, (3) down-time, (4) availability, (5) failure rates, and (6) replacement (consumption) rates.

The report forms are packaged between manila tag covers and flaps, with 50 sets per package.

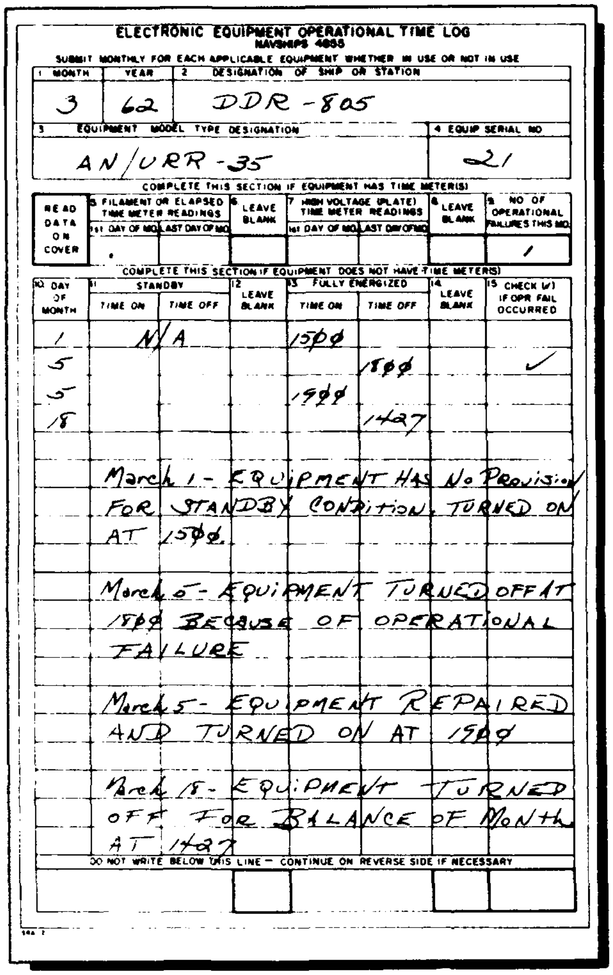
The covers and flaps have printed codes and instructions for accurately completing the entries on the new DD-787 form.

Electronic Equipment Operational Time Log, NavShips 4855

The electronic equipment operational time log (fig. 4-4) serves a twofold purpose. First, it is used to show accurate time-base data for figures-of-merit, which concern all failure-rate or replacement-rate calculations, or which concern other calculations that show reliability and maintainability factors. Second, it shows periods of actual operation versus inoperative periods; such period values are known technically as equipment population figures.

Without operational time or population figures that are reasonably accurate, any one or more figures of merit are not significant. Therefore, one realizes how the operational time log is essential in evaluating other reports, especially the previously described DD-787.

The operational time log form is relatively simple to complete, especially when an equipment is supplied with time meter(s). Only five or six entries need to be made on the first day of a month (depending upon the number of meters), and three more on the last day of the


ELECTRONIC EQUIPMENT OPERATIONAL TIME LOG
NAVSHIPS 4855
SUBMIT MONTHLY FOR EACH APPLICABLE EQUIPMENT WHETHER IN USE OR NOT IN USE

1 MONTH	YEAR	2 DESIGNATION OF SHIP OR STATION
3	62	DDR-805

3 EQUIPMENT MODEL TYPE DESIGNATION	4 EQUIP SERIAL NO
AN/URR-35	21

COMPLETE THIS SECTION IF EQUIPMENT HAS TIME METER(S)

READ DATA ON COVER	5 FILAMENT OR ELAPSED TIME METER READINGS (1st DAY OF MO.)	(LAST DAY OF MO.)	6 LEAVE BLANK	7 HIGH VOLTAGE (PLATE) TIME METER READINGS (1st DAY OF MO.)	(LAST DAY OF MO.)	8 LEAVE BLANK	9 NO OF OPERATIONAL FAILURES THIS MO.
							1

COMPLETE THIS SECTION IF EQUIPMENT DOES NOT HAVE TIME METERS

10 DAY OF MONTH	11 STANDBY TIME ON	TIME OFF	12 LEAVE BLANK	13 FULLY ENERGIZED TIME ON	TIME OFF	14 LEAVE BLANK	15 CHECK (✓) IF OPR FAIL OCCURRED
1	N/A			1500			
5					1500		✓
5				1900			
18					1427		

March 1 - EQUIPMENT HAS NO PROVISION FOR STANDBY CONDITION. TURNED ON AT 1500.

March 5 - EQUIPMENT TURNED OFF AT 1500 BECAUSE OF OPERATIONAL FAILURE

March 5 - EQUIPMENT REPAIRED AND TURNED ON AT 1900

March 18 - EQUIPMENT TURNED OFF FOR BALANCE OF MONTH AT 1427

DO NOT WRITE BELOW THIS LINE — CONTINUE ON REVERSE SIDE IF NECESSARY

15.3

Figure 4-4.—Electronic equipment operational time log, NavShips 4855.

same month; a total of 8 or 9 block entries (on a single form) are to be completed per equipment per month.

Equipments without time meters require somewhat greater effort. The format for packaging and using these forms are explained in detail on the covers (similar to the DD-787).

Electronics Performance and Operational Report, NavShips 3878

The Bureau must keep tab on new (and converted) equipments to evaluate their usefulness. This is accomplished with the subject report, NavShips 3878, shown in figure 4-5.

It is not desired that reports be submitted on all equipments. Reports are to be submitted only on those equipments listed in the EIMB. Any listing in EIMB is changed periodically to delete certain equipments and add others. A report is NOT required if an existing equipment has not been in operation. When applicable, NavShips 3878 is submitted monthly to the Bureau of Ships.

The NavShips 3878 reports are essential to keeping the Bureau informed on equipment performance and operation. Because they provide firsthand information on equipment under actual operating conditions and report the maximum ranges obtained, they are extremely valuable in evaluating the electronics maintenance program, enforcing manufacturer's guarantees, evaluating installation adequacy, improving equipment operation and safety, and improving equipment design.

The NavShips 3878 report contains a place for general remarks on the back of the form not shown in figure 4-5. Indicated here is any pertinent information not included elsewhere on the form such as detailed information on any unusual difficulty encountered in operation; exceptional maintenance required; and suggestions for improvement in design, tests, and new applications. The forwarding of suggested improvements is not to be construed, however, as authority to modify the equipment in any way. Nor does the forwarding of this report eliminate the separate requirement for forwarding the Electronics Failure Report (DD 787). Detailed instructions for preparing and submitting NavShips 3878 are contained in BuShips Instruction 9670.20D.

EQUIPAGE STOCK CARD AND CUSTODY RECORD

Tools and portable test equipment are equipage for which custody signatures are required. They are listed on Equipage Stock Card and Custody Records (Nav. S. and A. form 306), which are signed by the operations officer when he receives them from the supply officer. The electronics material officer (EMO) signs the custody record cards when he receives the tools and test equipment from the operations officer. The EMO then becomes responsible for them. He, in turn, issues them to the ETs. A memo receipt for equipage is signed by each ET when he receives a piece of equipment from the EMO, and the ET, in turn, becomes responsible to the EMO for the equipage.

ELECTRONIC PERFORMANCE & OPERATIONAL REPORT
NAVSHIPS 3878 (Rev. 4-60) *Submit original only to Bureau - No forwarding letter required*

FROM: USS RANGER (CVA-61) (Ship name, type and hull no.)	☐ LANT [X] PAC	REPORT CLASSIFICATION: UNCLASSIFIED	DATE: 1 Sep 61
TO: CHIEF, BUREAU OF SHIPS (CODE)		REPORTING PERIOD FROM 1 Aug 61	TO 31 Aug 61
TYPE AND MODEL OF EQUIPMENT: AM-1365/URT Amplifier		SERIAL NUMBER: 383	
FIELD CHANGES TO DATE — ACCOMPLISHED: None	NOT ACCOMPLISHED: None	HOURS DURING PERIOD OF THIS REPORT — OPERATED: 180	NOT IN OPERATING CONDITION: 564
PERFORMANCE FIGURE (PF) & TECHNICAL EVALUATION: ☐ OUTSTANDING ☐ GOOD ☐ SATISFACTORY [X] UNSATISFACTORY		OPERATIONAL EVALUATION: ☐ OUTSTANDING ☐ GOOD ☐ SATISFACTORY [X] UNSATISFACTORY	

RADAR

PEAK POWER OUTPUT (PT) dbm	AVER. VSWR IN TRANSMISSION LINE	AVER. ECHO BOX RING TIME YDS	MIN. DISCERNIBLE SIGNAL (PMDS) dbm
MAX. RANGE TARGETS DETECTED MI / MI / MI		MAX. ALTITUDE AT RANGE DETECTED MI / MI / MI	
MAX. ALTITUDE TARGETS DETECTED FT / FT / FT		RANGE AT MAX. ALTITUDE DETECTED FT / FT / FT	
TARGET CLASS. TYPE - DETAIL (SEE REVERSE)		TARGET CLASS. TYPE - DETAIL (SEE REVERSE)	
MAXIMUM RELIABLE RADAR RANGE MI		MINIMUM RELIABLE RADAR RANGE YDS	

SONAR

SOURCE LEVEL (LS) db//μBAR	RECEIVING SENSITIVITY db//VOLT/μBAR	SEA STATE	PROCEDURE USED			
NOISE LEVEL db//VOLT	5 KNOTS	10 KNOTS	15 KNOTS	20 KNOTS	25 KNOTS	30 KNOTS
MAXIMUM RANGE SONAR TARGETS DETECTED AND TRACKED	RANGING YDS		LISTENING YDS		SOUNDING FATHOMS	
TARGET CLASSIFICATION TYPE AND DETAIL						
BT PATTERN						
OWN SHIP'S SPEED	KTS		KTS		KTS	

COMMUNICATIONS

PERCENT OF TIME OUT OF CONTACT WHILE WITHIN RANGE (IF ANY)	ANTENNA SYSTEMS	INTERFERENCE (Frequencies, intensity, and sources)
0 %	No problems	No problems

POWER OUTPUT	AVERAGE VSWR	REL RANGE	RECEIVER SENSITIVITY
Voice 100 WATTS	1.5:1	40 miles	NA UVOLTS

ELECTRONIC WARFARE

MAXIMUM RANGE AND ALTITUDE TARGETS WERE DETECTED	MI	FT	MI	FT	MI	FT
TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE)						
MAXIMUM RELIABLE RANGE AND ALTITUDE	MI	FT	MI	FT	MI	FT
TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE)						
MAX. RANGE SONAR TARGETS DETECTED YDS	BT PATTERN		MAX. RELIABLE SONAR RANGE YDS		BT PATTERN	

35.83

Figure 4-5.—Electronics performance and operational report, NavShips 3878.

All equipage is inventoried once a year. The inventory is completed within the first quarter of the fiscal year and within thirty days after the date it is started. The Equipage Stock Card and Custody Record (not to be confused with Ship Electronics Installation Record, NavShips 4110) is used in making the inventory. The ETs may be called upon to assist the EMO in making this inventory, which consists of checking to make sure that the items listed on the Custory Record are in the department.

SHIP ELECTRONICS INSTALLATION RECORD, NAVSHIPS 4110

The Ship Electronics Installation Record, NavShips 4110, furnishes an up-to-date inventory of all electronic equipment aboard each ship to interested fleet and shore activities. For reporting purposes on the NavShips 4110 form, the ship's electronic equipment is divided into 7 major categories as follows: (1) communications, radio navigation, and countermeasures equipment; (2) radar and radar identification equipment; (3) sonar and sonar identification equipment; (4) test equipment; (5) formerly fire control electronic equipment, now deleted; (6) nancy and radiac equipment; (7) intercommunication equipment; and (8) power supply equipment.

Instructions for preparing, revising, and submitting NavShips 4110 are contained in NavShips 900-135 (revised).

MISCELLANEOUS RECORDS

Other records that concern the ET include a ship's plan index, rough work logs, division training records, stock control records, and maintenance and repair records. These records are discussed in the training courses for the higher ET rates.

CHAPTER 5

ELECTRONIC INSTALLATIONS

The purpose of this chapter is to give the prospective ET 3 an over all view of the equipments that he may be called upon to service as he becomes more familiar with electronic equipment.

Electronic equipment is rapidly being improved, and therefore much of the equipment discussed in the following paragraphs will eventually become obsolete. However, equipments are not replaced suddenly just as soon as new equipments are designed. Before large numbers of new equipment are installed, extensive tests and evaluations must be made; this takes time. Therefore, although a piece of equipment may be on the way out, it may still be used on certain ships for a considerable length of time.

Methods of installing electronic equipment (and the reasons why certain equipments are installed as they are) are important to the ET and are also included.

COMMUNICATION EQUIPMENT

Naval communications may be grouped into three categories as follows:

1. Electrical communications—which includes radiotelegraph (CW), radiotelephone (voice radio), teletypewriter, and facsimile.
2. Visual communications—which includes flaghoists, visible and invisible flashing light, and semaphore.
3. Sound communications—which includes amplified voice, whistles, sirens, bells, and sonar.

As an ET you will be concerned with the equipment used for electrical communications.

RADIO EQUIPMENT

Radio equipment may be classified in a general way as transmitters and receivers, the principles of which are discussed in Basic Electronics, NavPers 10087-A. Both transmitters and receivers are classified according to the frequency range that they cover, or the power output in the case of the transmitter.

There are no standard transmitters used aboard ship in the VLF band. The shore transmitters for this band are of special design and have power outputs ranging from 300kw to one million watts. Receivers that operate in the VLF band are installed aboard surface ships and submarines primarily to receive the radioteletype and CW fleet broadcasts from the VLF shore station transmitters. Communication in the VLF band is advantageous for surface ships and submarines operating in the arctic regions due to its reliability during electrical storms. It is particularly useful for submarine communications as the signals may be received while submerged. There are many shipboard transmitters and receivers used in the LF through the UHF bands.

Radio wave emissions (transmissions) have been classified by international agreement according to the type of modulation used (table 5-1).

Review of Modulation

Modulation is the process of varying either the amplitude or frequency of the r-f output of a transmitter at an audio rate. With amplitude modulation the strength (amplitude) of the r-f energy is made to vary in accordance with the audio signal amplitude variations. Modulating an r-f carrier with a single audio frequency of sine wave form produces three waves. These include the r-f (carrier), the sum of the carrier and the audio frequency (upper sideband) and the difference in the carrier and the audio frequency (lower sideband). When the amplitude of the r-f carrier is carried to zero during one half the modulating cycle and twice the unmodulated value during the other half cycle the modulation is said to be 100 percent. For

this condition the sidebands contain the maximum permissible amount of power (one-half the carrier power). Modulation in excess of 100 percent causes distortion and loss of sideband power.

Single Sideband

Single sideband (SSB) communication systems have become increasingly important in Navy applications.

Table 5-1.—Classification of Radio Emissions.

Symbol	Type of transmission
	Amplitude modulated
A0	Continuous wave, no modulation.
A1	Continuous-wave telegraphy. On-off keying.
A2	Telegraphy by keying of a modulated emission.
A3	Telephony. Double sideband, full carrier.
A3a	Telephony. Single sideband, reduced carrier.
A3b	Telephony. Two independent sidebands with reduced carrier.
A4	Facsimile.
A5	Television.
A9	Composite transmissions and cases not covered by above classifications of emissions.
A9a	Composite transmissions, reduced carrier.
	Frequency (or phase) modulated
F0	Absence of modulation.
F1	Telegraphy by frequency shift keying, with no modulation.
F2	Telegraphy by keying of a modulating audio frequency. Also by keying of modulated emission.
F3	Telephony.
F4	Facsimile.
F5	Television.
F9	Composite transmissions and cases not covered by above classification of emissions.
	Pulse modulated
P0	Absence of modulation intended to carry information (such as radar).
P1	Telegraphy. No modulation of audio frequency.
P2d	Telegraphy by keying an audio frequency which modulates the pulse in its amplitude.
P2e	Telegraphy by keying an audio frequency which modulates the pulse in its width.
P2f	Telegraphy by keying an audio frequency which modulates the pulse in its phase (or position).
P3d	Telephony. Amplitude modulated.
P3e	Telephony. Width modulated.
P3f	Telephony. Phase (or position) modulated.
P9	Composite transmissions and cases not covered by above classification of emissions.

In order to understand what is meant by SSB transmission, you should review the pages of Basic Electronics, NavPers 10087 (revised) which discuss conventional amplitude modulation.

A receiver tuned to a conventional AM signal having upper and lower sidebands will detect the intelligence in the sidebands by heterodyning the carrier with the upper and lower sidebands to yield the audio modulating signal. The only function of the carrier is to provide this heterodyning process at the second detector. If the carrier were absent the signal could be recovered at the second detector by reinjecting the carrier derived from a local oscillator at the receiver provided its phase were the same as that of the carrier at the transmitter. By using this method the power in the transmitted carrier can be saved since it is not radiated from the transmitting antenna.

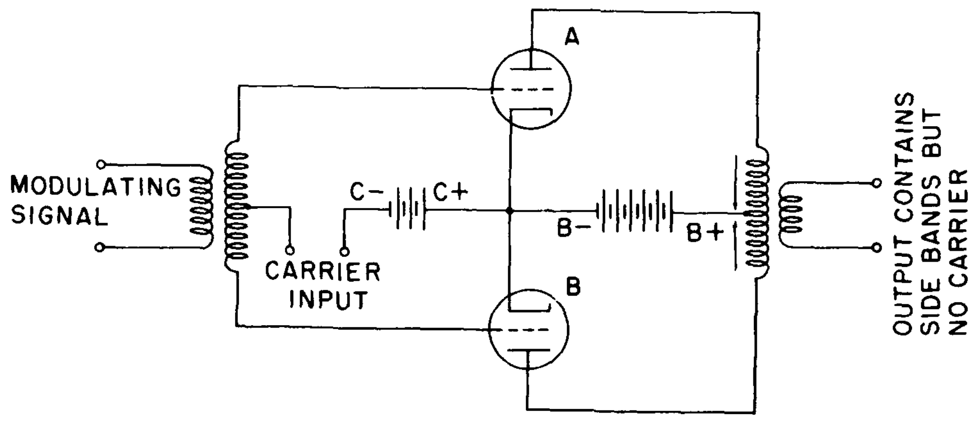
SUPPRESSED CARRIER.—The r-f carrier may be eliminated by using a balanced modulator in one of the early r-f stages of the transmitter so that the sidebands are produced, but no pilot carrier will be present. A simplified circuit of a balanced modulator is shown in figure 5-1A.

The carrier is applied with the same magnitude and instantaneous polarity to both grids of the push-pull circuit, and is therefore canceled in the output. The modulating signal, however, produces opposite instantaneous polarities at the grids of tubes A and B; the sideband components are likewise of opposite phase and appear in the output. If only one sideband is to be transmitted, a suitable filter may be used to pass the desired sideband and suppress the other. That is, when speech is fed into the transmitter the carrier itself does not appear in the output. What appears at the output is sideband energy or "talk power."

TRANSMITTING SSB.—If one of the two sidebands is "filtered" or "phased out" before it reaches the transmitter power amplifier, the intelligence can be transmitted on the remaining sideband. All of the power is then transmitted in one sideband, rather than being divided between the carrier and the two sidebands as in conventional AM. For example, in AM (for 100 percent modulation), when the output power is 150 watts, 100 watts is contained in the carrier and 25 watts in each of the sidebands, or a total of 50 watts in both sidebands. In SSB, all of the power is put into one sideband.

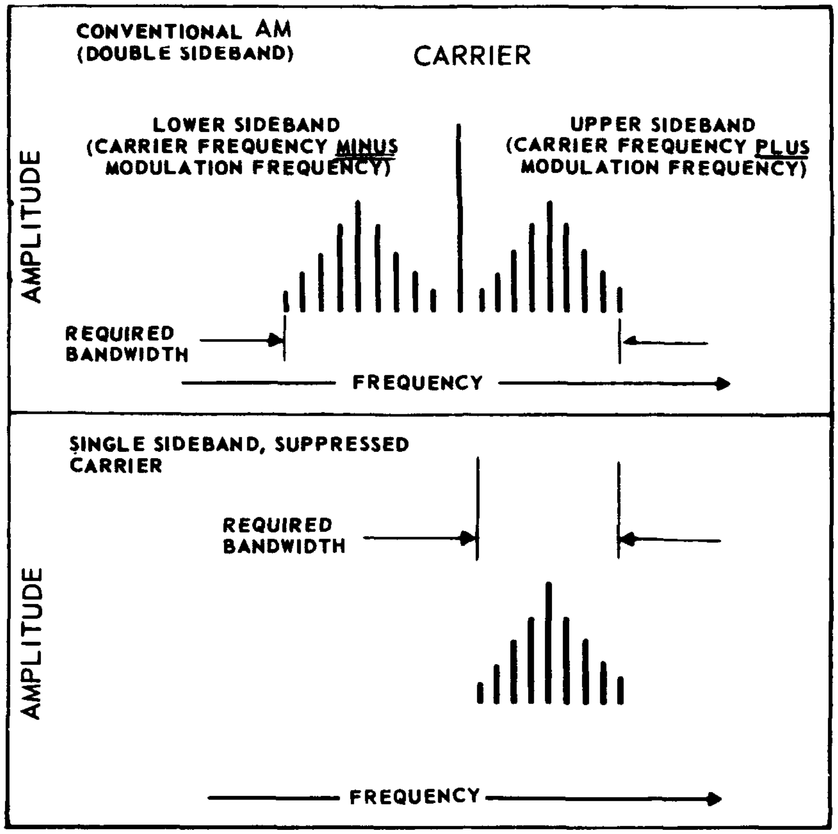
Thus, theoretically, a radiated power of 50 watts at the transmitter employing SSB is equivalent to a radiated power of 150 watts at the transmitter when conventional AM is used. Equally important, the bandwidth required for a SSB voice circuit is approximately half that needed for conventional AM (see fig. 5-1B).

Receiving SSB.—The SSB receiver must have rigid frequency stability, much more so than when conventional AM is used. The SSB receiving station has the problem of furnishing an artificial carrier, because the SSB signal does not have a carrier against which the sideband



70.8.0

Figure 5-1A.—Balanced modulator.



70.9

Figure 5-1B.—Comparison of DSB and SSB bandwidths.

signals can be heterodyned in the receiver (during the demodulation process) to produce useful audio signals.

Normally, the artificial carrier is furnished by a beat-frequency oscillator in the receiver. This method of carrier reinsertion is not to be confused with those commercial SSB transmitters that transmit a residual (not totally suppressed) carrier signal, so that automatic frequency-control equipment may be used. Such is the type used in the Navy's fixed shore installations.

It is necessary that the SSB transmitter have the same high order of stability as the receiver. The transmitter and receiver must not drift apart more than a very few cycles for quality voice reception.

ADVANTAGES OF SSB.—In conventional AM, if the sidebands are not received in the proper phase (due largely to multipath skywave propagation conditions), the signal is fuzzy, distorted, and sometimes quite loud. However, with the suppressed-carrier type of SSB, this problem is greatly reduced.

There is, as has been stated, an increase in effective power because all of the power goes into the single sideband, which carries the useful voice intelligence. Th power gain in the SSB system is from 6 to 9 db over the equivalent conventional AM system. The SSB transmitter provides about 6 db of gain, and about 3 db of gain results from the narrowband, single-sideband receiver.

Essentially the number of available channels is doubled when SSB is used. Doubling the number of channels in the 2 to 30 mc range is especially important in fleet communications.

In some voice conventional AM communications systems the carrier remains on the air

during periods when modulation is absent. If one station transmits while another (having nearly the same carrier frequency) is on, the result is interference (squeals).

In SSB, with voice break-in, as soon as the individual stops speaking into the microphone, "talk power" in the sideband leaves the air so that interference is reduced. A ship may enter the network as soon as the "talk power" leaves the air. Even when two stations transmit at the same time, a receiving station can read through the interfering station the same way you are able to choose one conversation from several going on around a conference table.

A brief discussion of radio equipment in use aboard Navy ships follows.

Transmitters

The TBL (7 to 13) operates in the 175-kc to 600-kc (LF-MF) range and also in the 2-mc to 18.1-mc (MF-HF) range; it is capable of A1, or A3 emission at 200, 100, and 50 watts, respectively. The standard installation includes speech input equipment and one or more remote radiophone units.

The TBK (7 to 20) operates in the 2-mc to 18.1-mc (MF-HF) range. The output is 500 watts on A1 only.

The AN/SRT (14, 15, 16 series) operates in the 0.3-mc to 26-mc (MF-HF) range on A1, A3, F1, and F4 emissions at 100 or 500 watts, and is described in chapter 9 of this training course.

The AN/URC 32 is a manually operated radio communications transceiver for operation in the 2 to 30 mc (high frequency) range with a transmitting peak envelope power (pep) of 500 watts except on A9a emission. Emission types include A1, A3a&b, A9, A9a and F1 (table 5-1). Additional information on this radio set is given in chapter 9 of this training course.

The TED series operates in the 225-mc to 400-mc (VHF-UHF) range on A2 or A3 emissions.

Additional transmitters presently in use are listed in table 5-2.

Receivers

The AN/SRR (11, 12, and 13) operates in the 14 kc to 32 mc (VLF-LF-MF-HF-VHF) range. The sets are designed for general application

Table 5-2—Radio Transmitters.

Model	Frequency Range	Emission	Power Output	Intended Use
AN/WRT-1	300-1500 kc	A1, F1, A3	500 w	MF Shipboard communications
AN/WRT-2	2-30 mc	A1, A3, A3a A3b, F1	500-1000 (PEP) w	HF Shipboard communications
AN/URT-17	2-32 mc	A1, A2, A3 A3a&b, F1, F4	750-1000 w	HF Ship and Shore Communications
AN/URC-7 Transmitter-Receiver	2-7 mc	A3	25 w	MF Ship and Shore Communications
AN/URT-7	115-156 mc	A2, A3	30 w	VHF Ship and Shore Communications
AN/GRC-27 Transmitter-Receiver	225-400 mc	A2, A3	100 w	UHF Ship and Shore Communications

in all types of ships. Circuits are provided for the reception of four classes of emission—A1, A2, A3, and F1 in the appropriate bands. These receivers are described in chapter 9 as examples of common operating adjustments of electronic equipments.

The AN/URR (13 and 35) operates between 225 mc and 400 mc (portions of the VHF/UHF bands). The sets are designed to receive A2 and A3 transmissions on ships or at naval air and shore radio stations.

The AN/URR-27 performs essentially the same functions, except that it covers only a portion (150 mc to 190 mc) of the VHF band.

The RBA, RBB, and RBC receivers, although being replaced by the AN/SRR-11, 12, and 13, are still in use aboard some ships. The RBO, the standard shipboard entertainment receiver, is being replaced by the AN/URR-22. The AN/URR-22 can also be used as an emergency communication receiver for CW and MCW signals. It covers the frequency range of 540 kc to 18.6 mc in four frequency bands.

Receiver R-390/URR is a modern receiver for both shipboard and shore station use covering frequencies from 0.5 mc through 32 mc. It can receive A1, A2, A3, and F1 emissions, used in conjunction with converter CV-5911/URR, A3a and A3b (SSB) signals may be received.

The AN/WRR-2 is a modern receiver for shipboard and shore station use. Frequencies from 2 to 32 mc are covered for A1, A2, A3, A9, F1, and F4 emissions.

RADIO TELETYPE TERMINAL EQUIPMENT

A brief description of radio teletype systems is necessary before a description of the individual components can have any real meaning. More of the details are given in chapter 10 of this training course.

The Navy uses two radio teletype systems afloat. One, the TONE-MODULATED system for short-range operations, is similar to the familiar AM radio. The other, the CARRIER FREQUENCY-SHIFT system for long-range operations, is similar to standard FM radio.

Tone-Modulated System

The tone-modulated system is illustrated in figure 5-1C. The teleprinter (TTY) sends out a signal consisting of direct-current, on-and-off pulses. An "on" or "current" interval is called a MARK or MARKING impulse. An "off" or "no-current" interval is called a SPACE or SPACING impulse.

The marks and spaces, designated as M and S in figure 5-2, are generated in various code groups of five units each. The group shown in figure 5-2 is for the letter "H."

A knowledge of the specific groupings is incidental to a basic understanding of the operation of the radio teletype system. The important thing to know is that the succession of direct-current "marks" and "spaces" in fixed-timed intervals conveys both intelligence and synchronization from one teleprinter to another.

To transmit messages by the tone-modulated system (fig 5-1C (1)), a teleprinter, a tone terminal, and a transmitter are needed. The teleprinter sends out a direct-current signal of marks and spaces, and the signal is changed to either of two audio tones in the tone terminal. The tones may be 500 cycles for a space and 700 cycles for a mark. The transmitter impresses the audio tones on the carrier and sends out an amplitude or tone-modulated carrier wave.

To receive messages with the tone-modulated system (fig 5-1C (2)), a radio receiver, a tone converter, and a teleprinter are needed. The tone-modulated carrier wave enters the receiver, which extracts the signal intelligence and sends the audio tones to the tone converter. The converter changes the audio tones into direct-current mark and space pulses for the teleprinter.

In practice, the same tone terminal is used for both the sending and the receiving circuits because it contains both a transmit "keyer" unit and a receiver "converter" unit.

Frequency-Shift System

The frequency-shift system is illustrated in figure 5-3. At the transmitting end of this system (fig. 5-3, A) are a teleprinter; a frequency-shift keyer unit, which is built into the newer transmitters; and a transmitter (XMIT). In some older systems, the keyer unit is a separate piece of equipment.

When the teleprinter is operated, the direct-current teleprinter mark and space signals are changed by the keyer unit into frequency-shift intervals. The frequency-shift intervals are transmitted as carrier frequency-shift (CFS) signals. The carrier shift is very small compared with the frequency of the carrier; it may be of the order of 850 cycles.

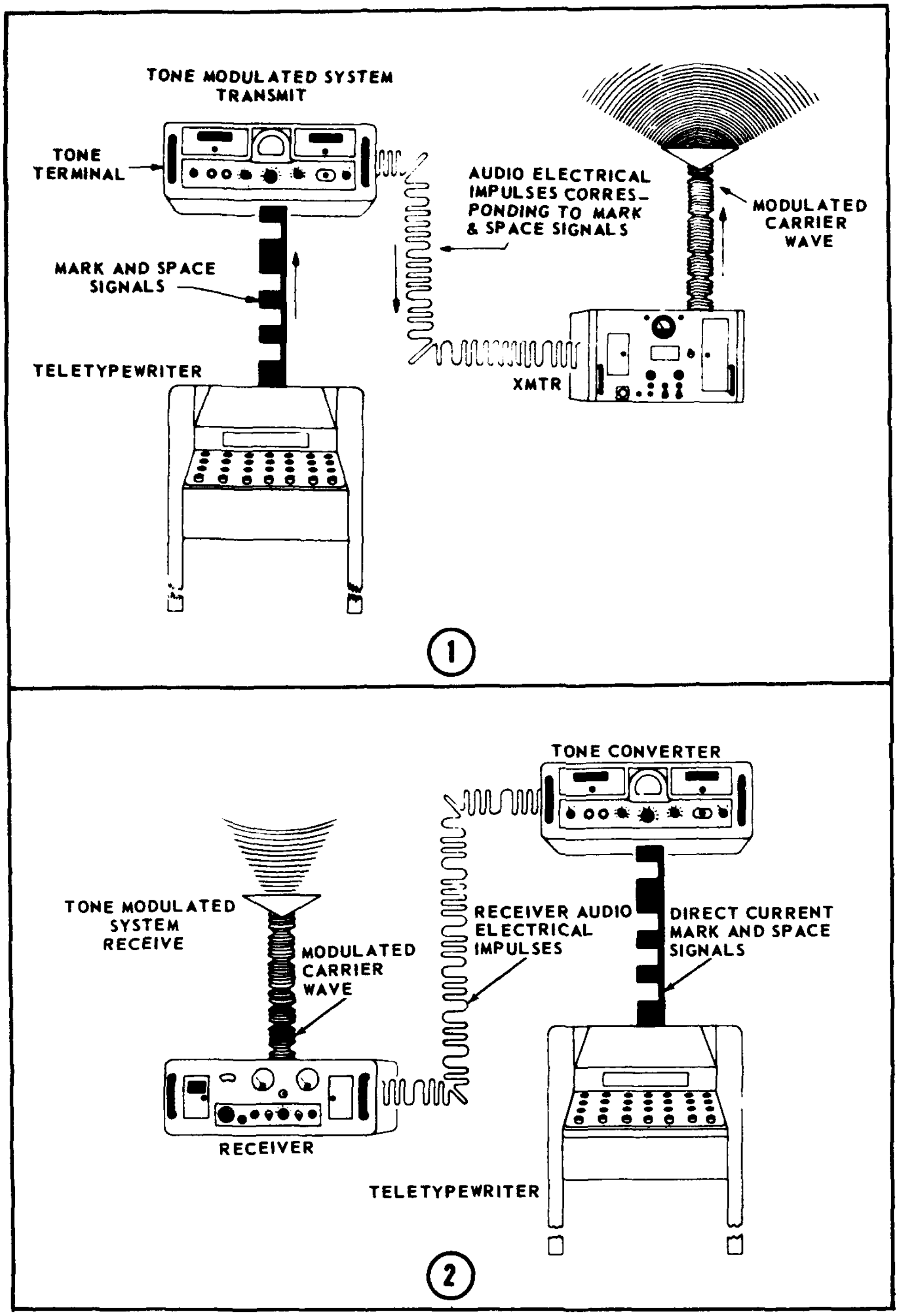


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Figure 5-1C.—Tone-modulated system.

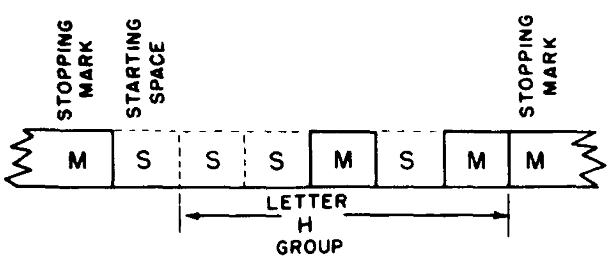

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Figure 5-2.—Teletype code group.

On the receiving side of this system (fig. 5-3, B) are a receiver, a frequency-shift converter, and a teleprinter. When the carrier frequency-shift signal enters the receiver, it is detected and changed into a corresponding frequency-shifted audio signal. The audio output of the receiver is fed to the converter, which changes the frequency-shifted audio signal into the direct-current mark and space teletype signals. The tone converter in the tone-modulated system is similar to the carrier frequency-shift converter in the frequency-shift system.

Basic Radio Teletype
System

When the carrier frequency-shift system (long range) is combined with the tone-modulated system (short range), several more pieces of equipment are needed—a TELETYPE PANEL, a POWER SUPPLY, a SWITCHING CONTROL, a TRANSMITTER SWITCHBOARD, and a RECEIVER SWITCHBOARD, as illustrated in figure 5-4.

The teletype panel is capable of handling six channels, or "loops." The power supply furnishes the direct "looping" current for all teletype direct-current signals. Located at the teleprinter is the switching control, which is used to select the desired system. The transmitter and receiver switchboards are used to join the radio teletype systems with other communication systems on board ship.

As has been stated, the tone-modulated system and the carrier-frequency-shift system are combined to form one teletype system in shipboard communications. The tone-modulated system is used only for short-range, or "line-of-sight," communications in the UHF band. Manmade and atmospheric static and signal fading are not major problems in this band, and no special equipment to counteract these effects is needed.

The frequency-shift system, used in the LF to HF bands, is the best way to send the rapidly keyed signals of the teletypewriter over long distances. Fading and interference are sometimes major problems in these bands.

Because a single r-f carrier usually does not fade simultaneously in areas separated by more than one wavelength, and because fading of carriers of different frequencies usually does not occur simultaneously at the same point, the Navy has taken advantage of this situation by the use of two methods of DIVERSITY RECEPTION (fig. 5-5).

In SPACE DIVERSITY (fig. 5-5A) reception one signal is transmitted, and this signal is received by two receivers. Antennas for these receivers are separated by a distance greater than one wavelength. The outputs of the receivers are fed into two frequency-shift converters and then into a COMPARATOR, which selects the best signal for the teletypewriters.

In FREQUENCY DIVERSITY reception (fig. 5-5B), two or more identical signals are transmitted on different frequencies. Two receivers, tow converters, and a COMPARATOR are used, as in space diversity. The receiving antennas are not separated.

For the tone-modulation system (higher frequencies), the transmitter may be the TED and the receiver may be the AN/URR-35; for the carrier frequency-shift system (lower frequencies), the transmitter may be the AN/SRT-14, and the receiver may be the AN/SRR-11, 12, 13 system.

A basic teletype system employing diversity reception is illustrated in figure 5-6.

Frequency Division
Multiplexing

To a great extent, the maximum permissible number of intelligible transmissions taking place in the radio spectrum per unit of time is being increased through the use of multiplexing. Multiplexing involves the transmission of several intelligible signals during the same period of time normally required for the transmission of a single signal. Either of two methods of multiplexing may be used. These are time-division and frequency-division multiplexing, respectively.

Frequency-division multiplexing is the older of the two methods of multiplexing. In this

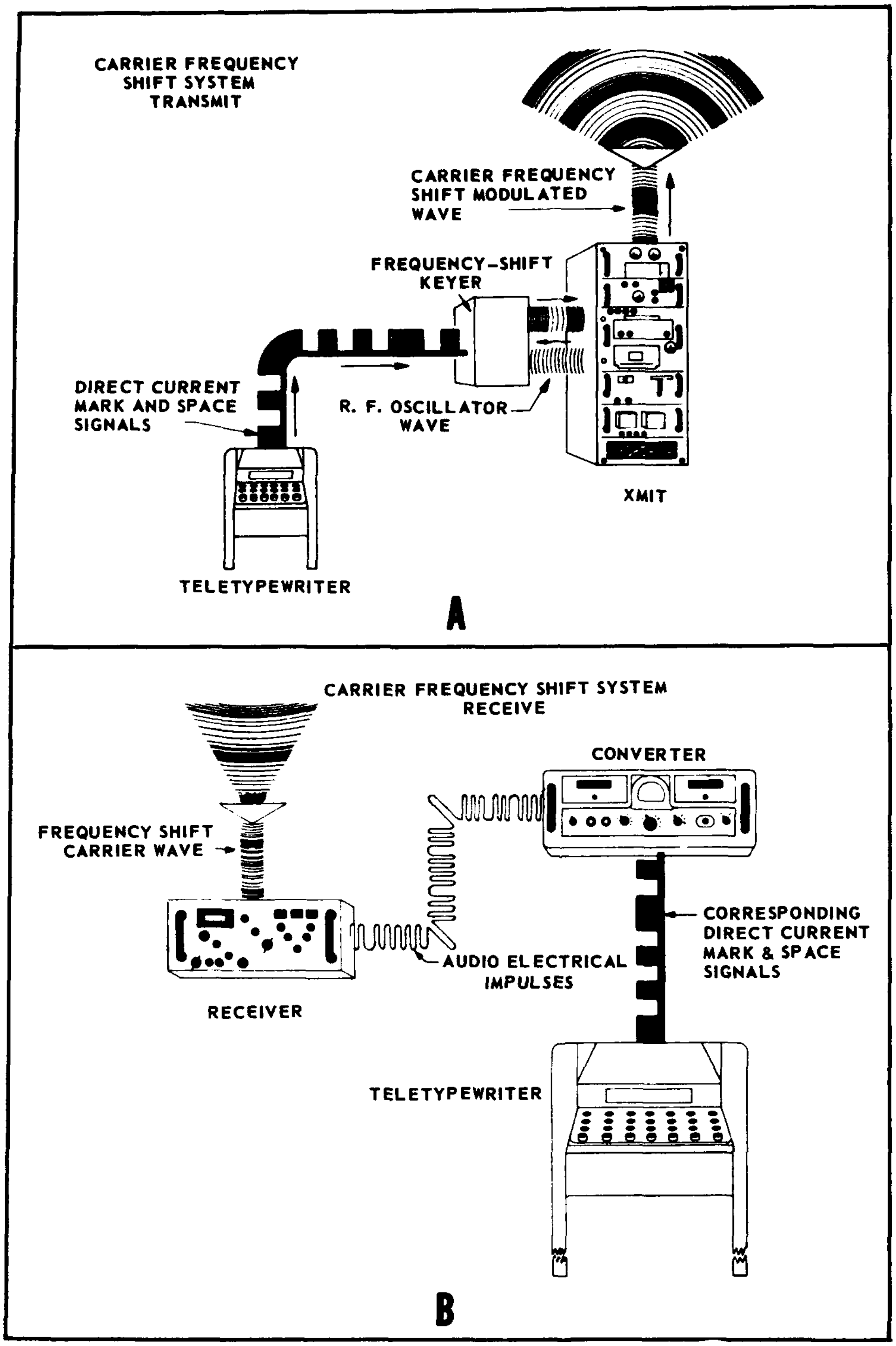

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Figure 5-3.—Frequency-shift system.

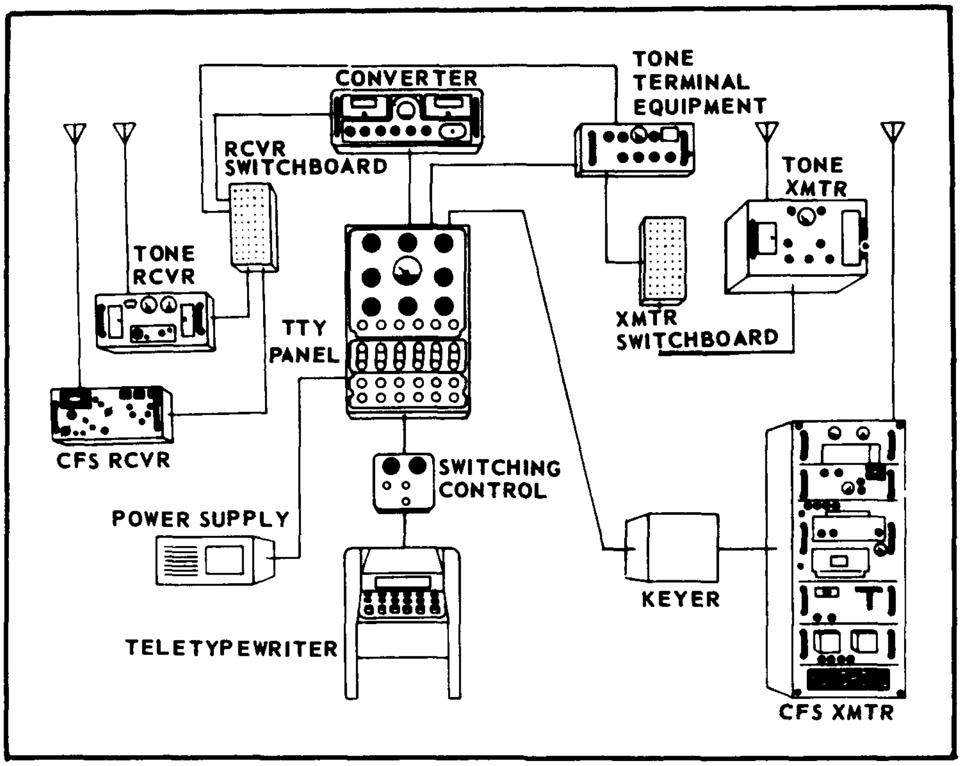

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Figure 5-4.—Basic radio teletype system.

system, different subcarrier frequencies are modulated by the signals of different channels, transmitted over the same cable (in the case of cable transmission) or on the same radio frequency carrier (in the case of radio transmission), then separated by filters before being demodulated. The total bandwidth, required for a frequency-division multiplexing system is the sum of the bandwidths of the individual channels, plus the sum of the necessary guard-band frequencies between channels.

Teletype Terminal Equipment AN/UCC-1

The AN/UCC-1 is a modular terminal for frequency shift carrier telegraph communication employing a frequency division multiplex system over single-sideband radio circuits, voice-frequency wirelines, microwave circuits, or other transmission systems. The equipment provides a total of 16 narrow-band channels, or 8 narrow-band and 4 wide-band channels, within the nominal 300 cps to 3300 cps frequency band. For space diversity operation, 16 transmitter channels and 32 receiver channels are available. A multiplexer-demultiplexer provides translation of a composite signal between this band and the nominal 3300 to 6300 cps frequency band so that 32 narrow-band channels or 16 narrow-band and 9 wide-band channels are available for communication over a 6 kc single-sideband radio circuit. The terminal is all solid state design, with plug-in modules.

The AN/UCC-1 is compatible in operation and can replace the AN/FGC-29, AN/FGC-60 and AN/FGC-61. Reduced size and weight make it suitable for installation on most surface ships.

Time-Division Multiplexing

Time-division multiplexing is the transmission of the intelligence of several teletypewriter circuits on a time-sharing basis in a character-by-character sequence (fig. 5-7).

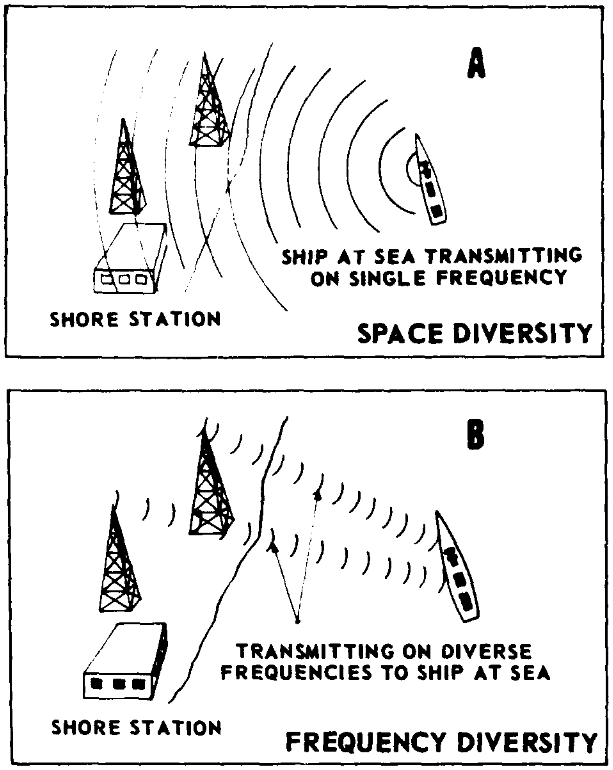

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Figure 5-5.—Diversity reception.

Information is fed into the multiplex equipment simultaneously from four teletypewriters. The same information is then transmitted from one multiplex equipment to the other in a time sequence with one character from each channel at a time. The receiving multiplex equipment then distributes the information to the proper teletypewriter circuits at telegraph speed.

Four characters are therefore transmitted over a single circuit during the time ordinarily required by one.

FACSIMILE EQUIPMENT

Facsimile equipment is used to transmit still images over an electrical communications system. The images, called pictures or copy in facsimile terminology, may be weather maps, photographs, sketches, typewritten or printed text, or handwriting. The still image serving as the facsimile copy or picture cannot be transmitted instantly in its entirety. Three distinct operations are performed. These are (1) scanning, (2) transmitting, and (3) recording.

Principle Of Operation

The SCANNING operation is that of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter (fig. 5-8) by a scanning drum and photocell arrangement.

The picture to be transmitted is mounted on a cylindrical scanning drum, which revolves at a speed of 1 revolution per second and travels along a lead screw at the rate of 12.5 inches in 20 minutes. (The lead screw has 96 threads per inch.) Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a photocell. During the transmission of a complete picture, the light traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the photocell is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The photocell transforms the varying amounts of light into varying electrical signals.

The fork oscillator unit develops an output voltage (MODULATION VOLTAGE) that is applied across the bridge modulator. The frequency of this voltage is 1800 cycles. When the bridge is balanced (photocell dark), the output voltage is zero. When the amount of light falling on the photocell varies, the resistance of the cell varies. This action unbalances the bridge and produces and output voltage that varies in amplitude with the variations in light. Thus, the 1800-cycle voltage is amplitude modulated in the bridge modulator.

The modulated signal is amplified in the voltage amplifier, the proper level is established in the gain control, and the signal is further amplified in the power amplifier before going to the radio circuits.

The fork oscillator unit, besides furnishing the carrier signal to the photocell bridge modulator, also supplies an 1800-cycle signal to the amplifier for the exciter lamp. This output keeps the exciter lamp at constant brilliancy. The fork oscillator output also supplies an 1800-cycle output to the synchronous motor amplifier. The output of the amplifier is used to operate the synchronous motor that drives the scanning drum at constant speed.

Electrical signals RECEIVED by the facsimile receiver (fig. 5-9) are amplified and

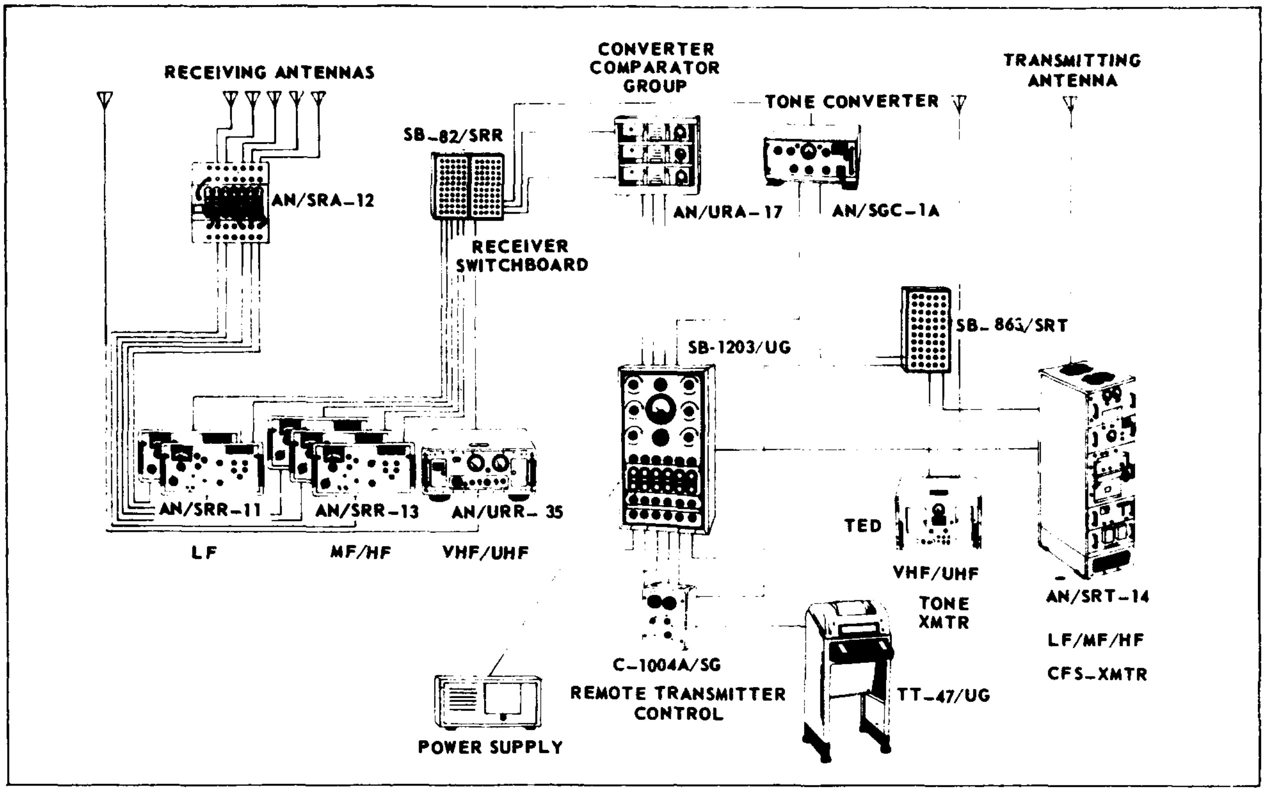

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Figure 5-6.—Teletype system employing diversity reception.

serve to actuate a recording mechanism that makes a permanent recording (segment by segment) on recording paper on a receiver drum similar to the one in the facsimile transmitter. The receiver drum rotates synchronously with the transmiter drum. This action continues until the complete original picture is reproduced in its entirety. The recording mechanism may reproduce photographically with a modulated light source shining on photographic paper or film; or, the recording mechanism may reproduce directly by burning a white protective coating from specially prepared black recording paper.

Synchronization is obtained by driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.

Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is properly phased with respect to the starting position of the scanning drum in the transmitter.

A start motor mechanically coupled to the synchronous motor serves to increase the synchronous motor speed above synchronism during the starting period after which it coasts down to synchronous speed when operating on 1800-cycle power.

The facsimile signal from the radio receiver circuit (fig. 5-9) is attenuated at the gain control, then amplified in the voltage and power amplifiers. The power amplifier output drives either the recording lamp for photographic recording, or the recording stylus for direct recording.

Another circuit from the power amplifier transmits phasing pulses to the phase amplifier, which operates the phase magnet and clutch during the phasing process just before each picture transmission.

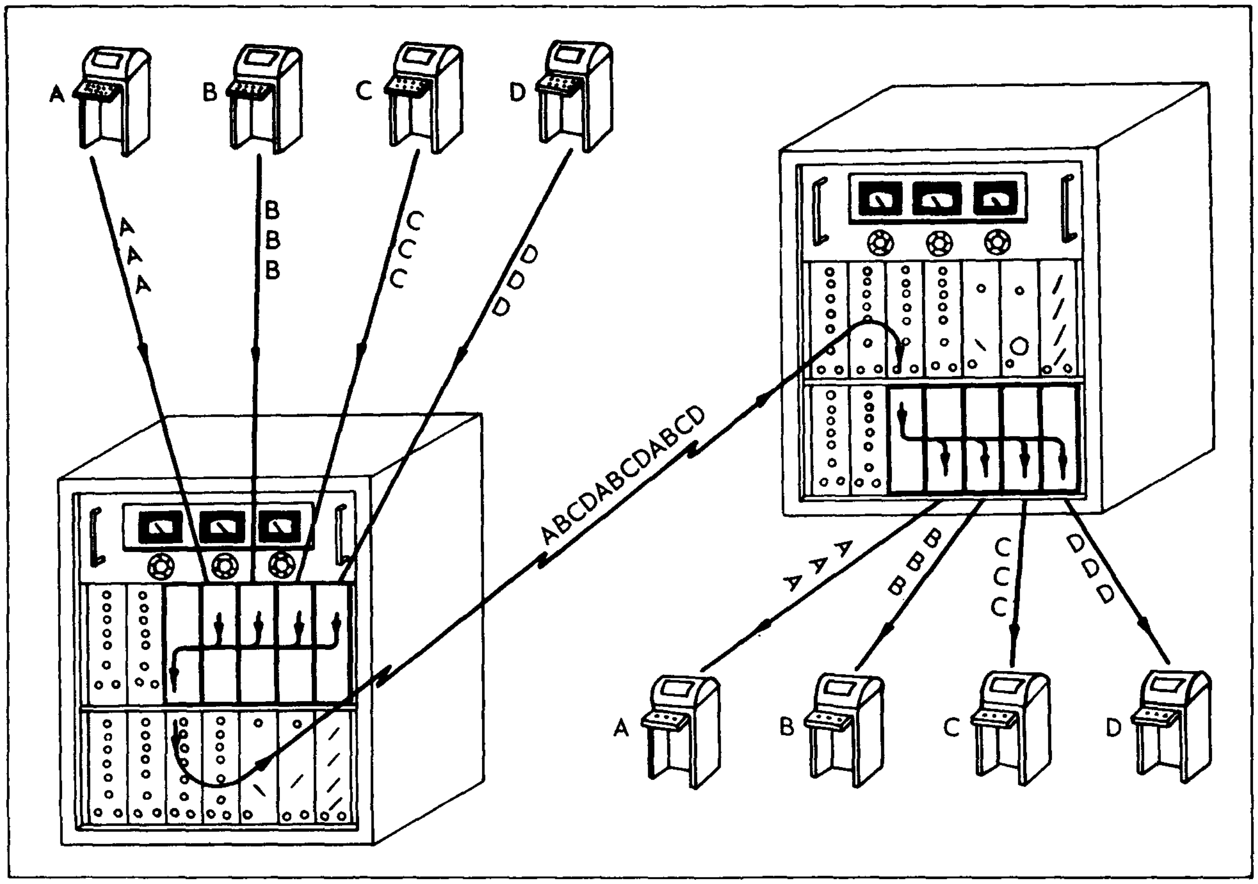

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Figure 5-7.—Time-division multiplex.

The fork oscillator serves a single purpose on receiving. It generates an 1800-cycle signal, which is amplified to operate the synchronous motor at the same speed as the motor in the transmitting transceiver.

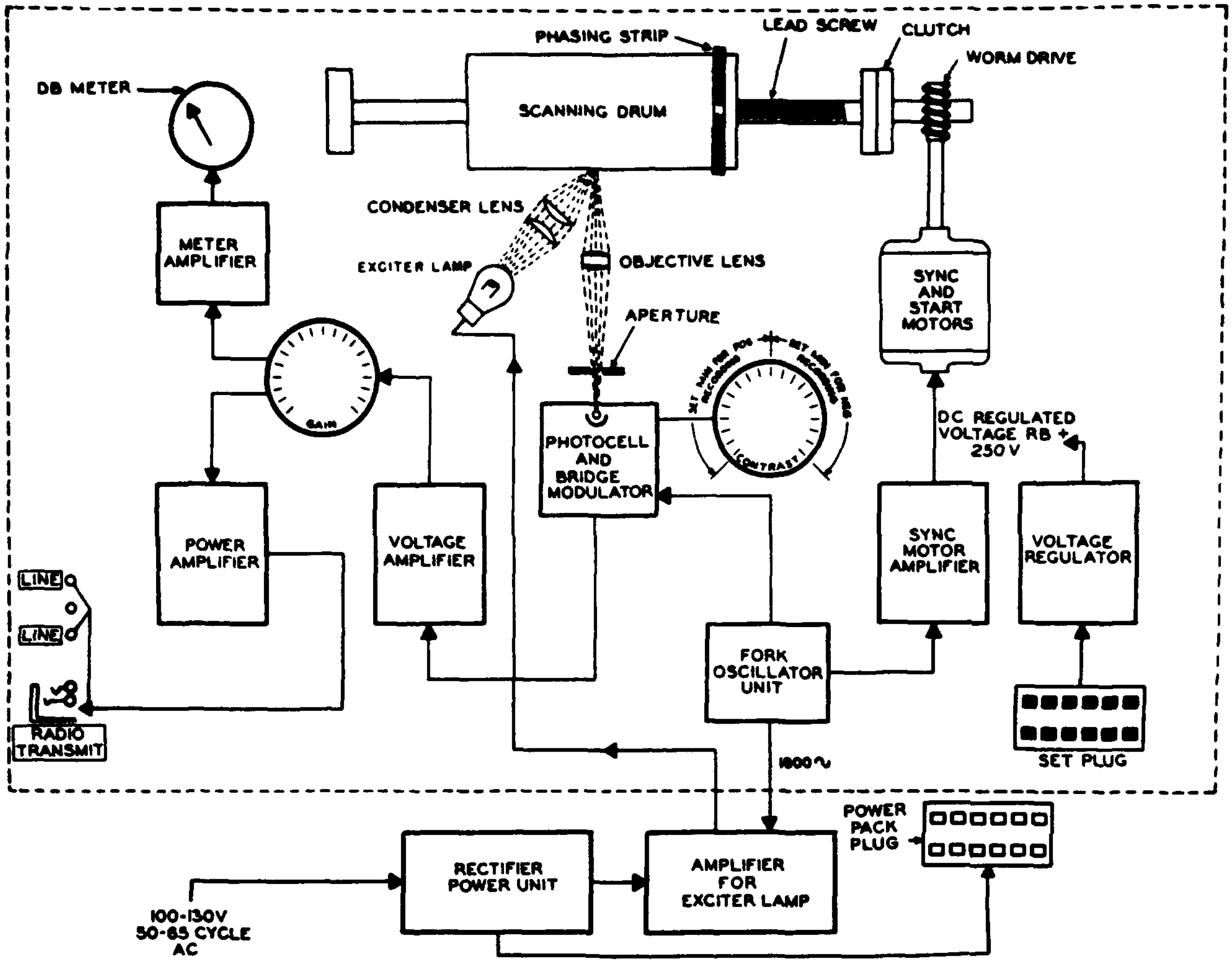
Basic Shipboard System

Present radio facsimile transmission is accomplished by the carrier frequency shift method (with a 400-cycle shift), which uses a standard radio transmitter and receiver.

Radio facsimile terminal equipment (fig. 5-10) at the TRANSMITTER consists basically of a facsimile transceiver TT-41( )/TXC-1B, which generates an 1800 cycle amplitude modulated tone frequency in accordance with the black, white, and contrasting shades of the picture that is being scanned. The audio signal is fed to a keyer adapter, KY-44(A)/FX, where it is converted to a d-c voltage. This voltage is used to control the output of the frequency shift keyer, KY-75/SRT. The output of the keyer frequency modulates the r-f carrier of a c-w transmitter.

Radio modulator MD168/UX is used between a TT-41(B)/TXC-1B transceiver and an A-3 equipped transmitter. The modulator converts the 1800-cycle, a-m signal from the facsimile transceiver to constant amplitude (frequency modulated or frequency shift) which varies at frequencies between 1500 and 2300 cycles. This frequency variation is suitable for connection to an A-3 radio transmitter. This method is known as audio frequency shift (AFC) transmission.

To RECEIVE either carrier frequency shift or audio frequency shift, the AN/SRR 11-13A series receiver is used with a CV-172( )/U



70.12

Figure 5-8.—Facsimile transceiver-transmitting block diagram.

frequency-shift converter. The CV-172( )/U frequency-shift converter changes the audio output (varying between 1500 and 1800 cycles) from the receiver back to an 1800-cycle, a-m signal suitable for operation of a facsimile recorder RD-92(A)/UX.

The facsimile signal is fed to or from the transceiver by way of a receiver switchboard similar to SB-82/SRR used in the teletype system illustrated in figure 5-6.

NAVIGATIONAL EQUIPMENT

Navigation equipments include a variety of electronic gear, each serving one or more specific purposes. Included among these equipments are radio direction finders, radio compass equipments, radio and radar beacons, loran (LOng RAnge Navigation), and others. Only brief descriptions of the various equipments are given in this chapter. A more detailed treatment of these equipments is included in the ET 2 training course.

RADIO DIRECTION FINDERS

The RDF (for strictly navigational use) finds little shipboard application today, although it is used in air navigation. Other devices, however, are very rapidly replacing the RDF, even in aircraft.

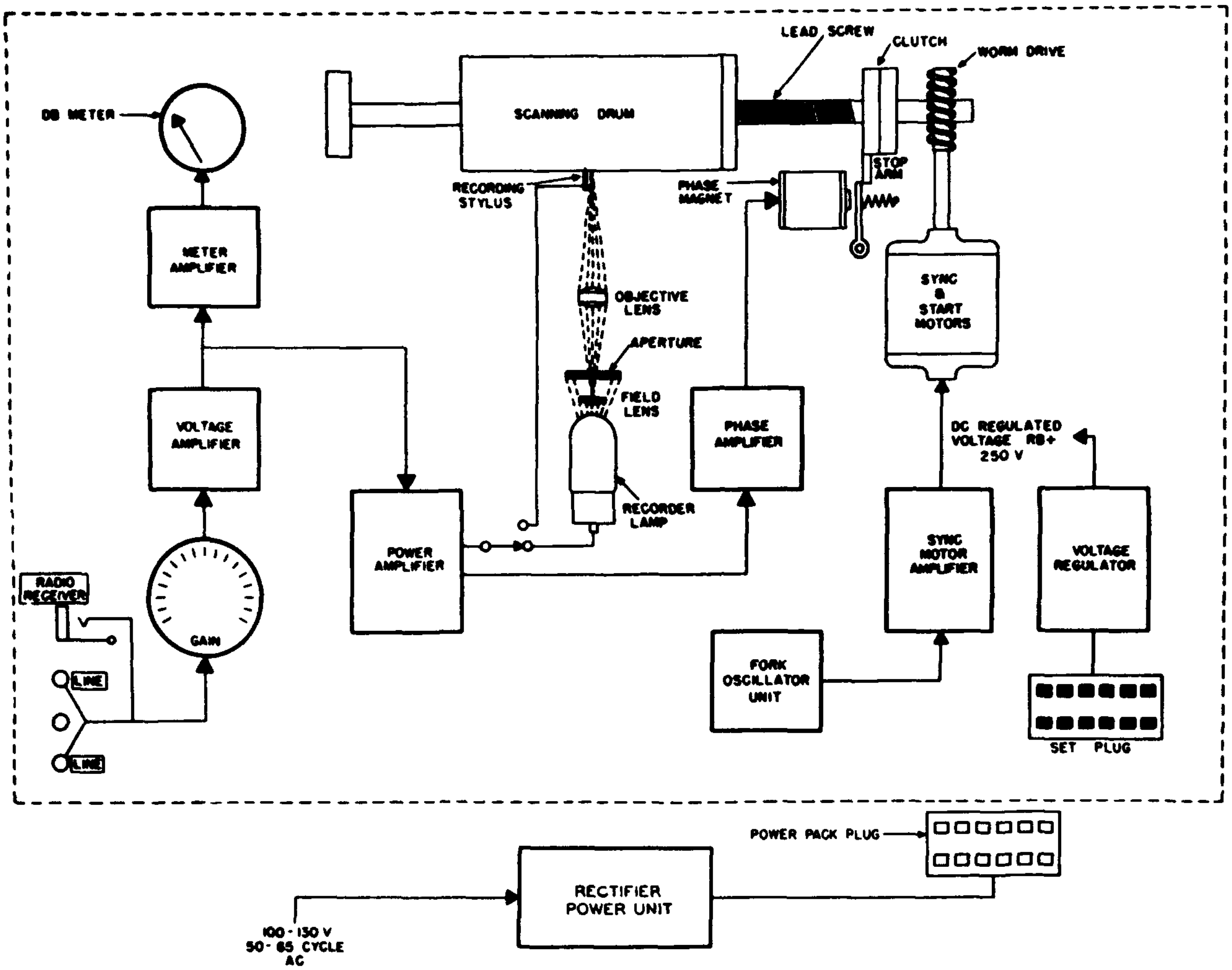


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Figure 5-9.—Facsimile transceiver-receiving block diagram.

One of the uses of RDF today is in the location of personnel afloat in liferafts or lifeboats having a radio transmitter on which ships or planes can take bearings.

The radio direction finder is a sensitive receiver to which a directional (loop) antenna is connected. Range information is not obtained with just one bearing alone. By taking bearings on at least two transmitters a position can be obtained.

Many older shipboard direction finders operated in the low-and medium-frequency bands because in these frequency ranges the bearing accuracy was increased. However, many of the newer special-purpose RDF equipments operate in the VHF, UHF, and SHF bands. One of the uses of these equipments is to enable the operator to obtain bearings on intercepted radio and radar signals of unknown origin.

RADIO COMPASS EQUIPMENT

Radio compass equipment finds its greatest present-day usage in aircraft. With a network of radio beacons covering much of the earth's surface, the radio compass is essentially a radio direction finder that automatically indicates the plane's bearing at all times and thus helps the pilot to maintain his course and to locate his position. Where the beamed energy

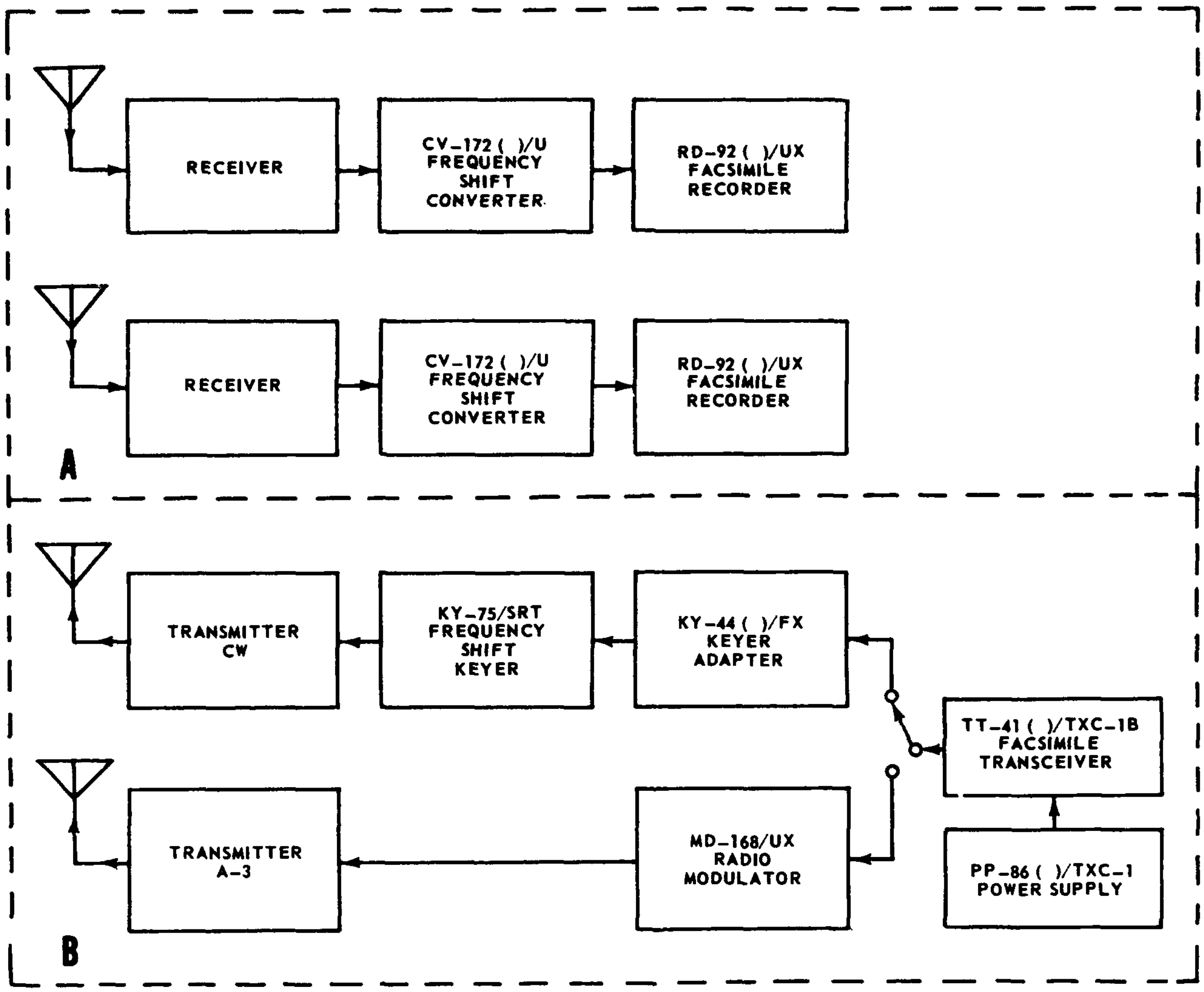

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Figure 5-10.—Radio Facsimile terminal equipment.

from the beacons cross, it is possible for the pilot or navigator to fix his position with considerable accuracy.

Ground-station radio beacons transmit either continuously or at automatically scheduled times; the pilot tunes his compass receiver to the frequency of the stations listed in the area through which he is passing. Indicators automatically show relative bearing information with respect to the station being received.

SECTOR BEACONS

In military applications, aircraft are guided to carriers and shore bases by means of homing beacons located on the carrier or base. The sector beacon is a special type of homing beacon. It transmits a directional beam from a rotating array that is coded differently in various sectors of its angular sweep.

Each sector has a different code letter so that a pilot can read the code to determine his approximate bearing with respect to the homing beacon.

Figure 5-11 illustrates the radiated signals that may originate in a beacon transmitting equipment. The combination of letters may be changed daily or hourly for purposes of security. The shaded areas in the pattern illustrate that the identification signal is transmitted at certain angular displacements rather than continuously.

TACAN

Tacan, an abbreviation of TACtical Air Navigation, is used by the U. S. Navy and the U. S. Air Force. It has replaced sector beacons discussed in the preceding section.

Tacan is an electronic navigation system which enables a pilot to instantaneously and continuously read the distance AND bearing of a fixed ground station or shipboard transmitter.

Tacan is a polar-coordinate system in which a ship or station installation of an AN/URN-3 (or the improved model, AN/SRN-6) transmitting set and an airborne AN/ARN-21 transmitter-receiver indicator gives bearing and distance information to a pilot (fig. 5-12).

In aircraft having the AN/ARN-21 the pilot can read on an azimuth indicator the position of the transmitting source in degrees of magnetic bearing from his aircraft. Also, the distance in nautical miles to the same reference point is registered as a numerical indication very similar to that of an automobile odometer (mileage indicator). In figure 5-12, the aircraft is 106 miles from the carrier and the ship is on a magnetic bearing of approximately 230° from the aircraft.

To provide a continuous navigation service through a large area, such as the continental United States, the system contains 126 selectable channels. As in television channel assignments, no two stations within interference distance of each other should be on the same channel.

The pilot can switch channels to select any tacan transmitter within maximum range that best suits his flight path.

To aid the pilot in his identification of a particular transmitter, the transmitter automatically transmits a three-letter tone signal in International Morse Code every 37.5 seconds. The aircraft receiver converts the signal to an audible tone that is heard in the pilot's headset.

Two frequencies are employed, as indicated in figure 5-13. One frequency (Y) is used for transmissions to the aircraft and another frequency (X) is used for transmission from the aircraft. The surface-to-air frequency carries bearing and range intelligence as well as

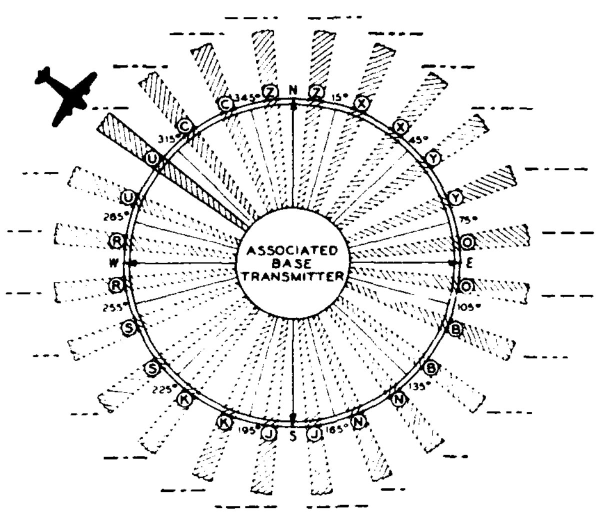

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Figure 5-11.—Radiated signal sectors of the Beacon Transmitter.

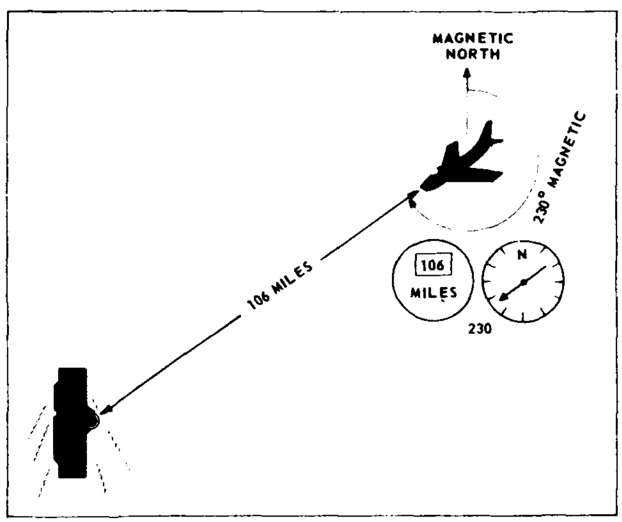

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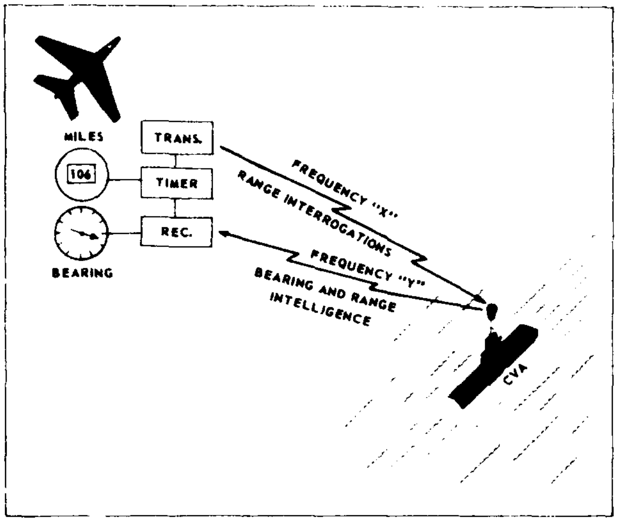
Figure 5-12.—Polar coordinate presentation of tacan data.



70.16
Figure 5-13.—Dual-frequency transmission.

station-identification information. The transmission from the aircraft-to-surface unit is required to trigger the distance-measuring system.

When the pilot closes the proper switch on his set control, his receiver-transmitter radiates a series of range interrogation pulses (frequency X).

The interrogation pulses are detected by any ship or station that is operating on the same channel. The pulses cause the transmitter to radiate a response, which is a series of pulses on frequency Y.

When the reply signal is received in the aircraft, it is fed to range circuits that determine the time that has elapsed during the round-trip of the two signals. Other circuits convert the time difference to equivalent dial indication in miles. Bearing information is radiated continuously on frequency Y.

Radio set AN/SRN-6 is replacing the AN/URN-3 as TACAN radio sets on board ship. The AN/SRN-6 system (fig. 5-14) comprises three major groups: receiver-transmitter, antenna, and power supply assembly.

As many as 100 aircraft may simultaneously obtain navigational information in conjunction with a single installation of the AN/SRN-6. The set is capable of receiving on any one of 126 frequencies (channels) in the range of 1025 to 1150 mc. Transmission of information also takes place on 126 channel frequencies in the ranges of 962 to 1024 mc and 1151 to 1213 mc.

Two types of antennas are available for use. Each antenna operates on 63 channels, corresponding to low-band frequencies and high-band frequencies, respectively. Low-band installations transmit at frequencies between 962 and 1024 mc inclusive, and receive at frequencies between 1025 and 1087 mc. High-band installations transmit in the range of 1151 to 1213 mc, and receive in the range of 1088 to 1150 mc.

Two frequencies are used in each channel: one for receiving, and one for transmitting. The frequency used for receiving in low-band installations is 63 mc above the frequency used for transmitting in the same channel.

LORAN

The loran system was designed to provide a means of obtaining navigational fixes by using low-frequency radio signals. The word LORAN is a combination of the first letters of the words LOng RAnge Navigation. With loran, accurate fixes (locating one's position) can be obtained at much greater distances from transmitting stations than is possible with conventional radio direction finding. During the day, over sea water, fixes are possible up to 700 nautical miles from the loran transmitting stations. During the night when sky waves are utilized, satisfactory operation may be obtained up to 1400 miles.

A loran fix compares favorably in accuracy with a celestial fix and it has certain advantages. It may be used as well in a heavy fog as in clear weather, and the readings can be made rapidly at any time.

The principle of loran is based on the difference in time required for pulsed radio signals to arrive from a pair of synchronized transmitters. Loran transmitters are installed on shore several hundred miles apart. The principle of loran is illustrated in figure 5-15. If in part A, stations A and B are pulsed simultaneously, the two pulses arrive at any point on the center line at the same time. This is evident from the geometry of the figure; and an observer, with the proper receiving equipment, could tell if he was on this line.

Suppose, however, that an observer is located closer to station A than to station B. Then the pulse from station A will arrive at his location before the pulse from station B. Assume that the time difference is 800 μs, as shown in part B. There are many points at which the receiving

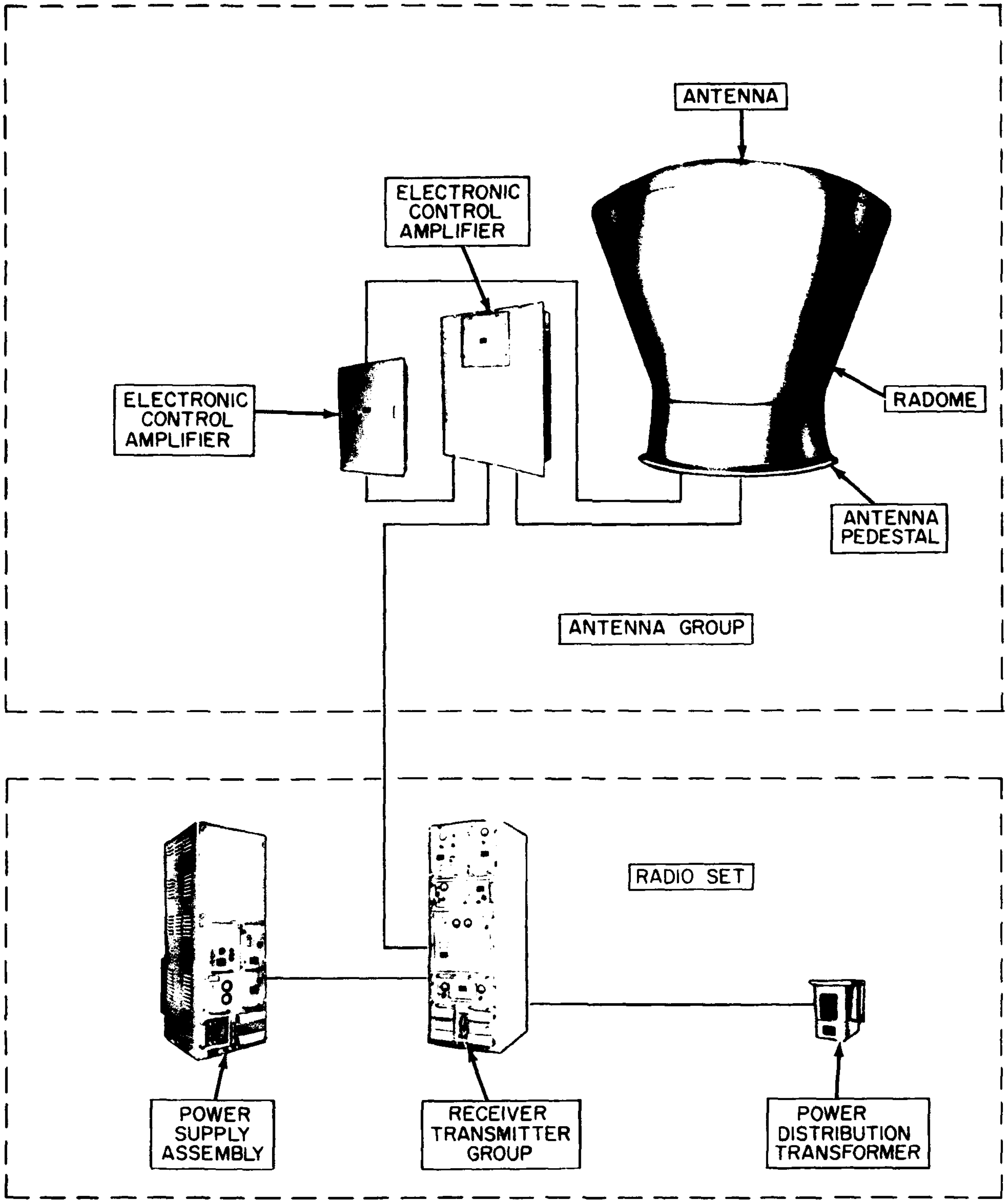


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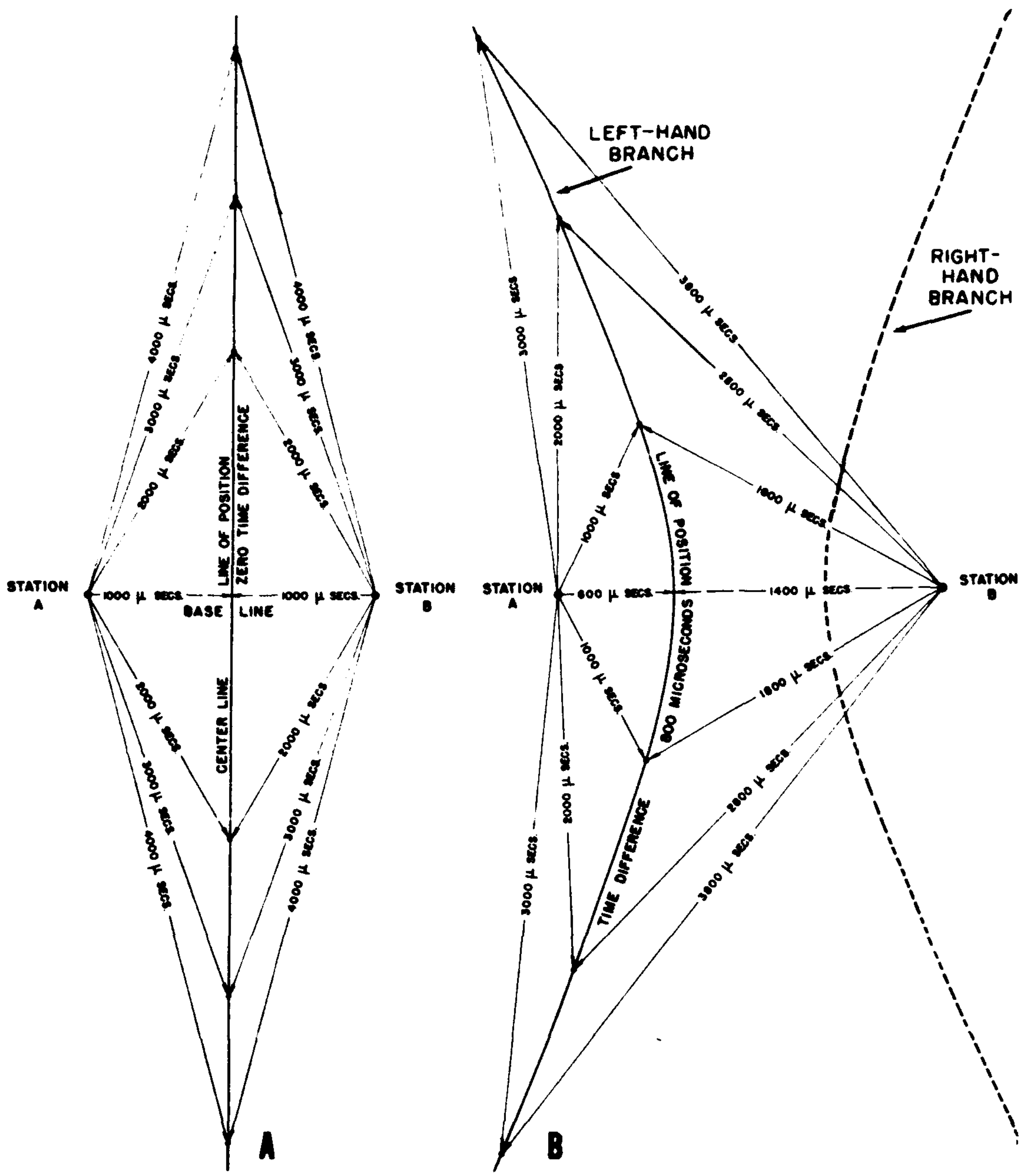
Figure 5-14.—Shipboard radio beacon using radio set AN/SRN-6.



12.34

Figure 5-15.—Principle of loran simplified.

equipment will indicate a time difference of 800 μs; these points lie on a hyperbola. Connecting the points where the time difference is the same forms a line of constant time difference, or hyperbolic line of position. This line (solid curved line) forms the LEFT BRANCH of the hyperbola. It is concave toward station A.

If the observer knows that he is closer to station A than station B and that the time difference is 800 μs, he still does not know

this exact position on the hyperbolic line of position.

Assume now that the observer is nearer station B than station A and that the time difference between the arrival of the two pulses is 800μs. The line of constant time difference is then the righthand branch of the hyperbola, and appears as the dotted curve in figure 5-15B. (Stations A and B are the foci of the hyperbola.) If the pulses from the transmitters are identical, the observer has no way of telling which pulse arrives first. He then cannot determine on which branch of the hyperbola he is located. This difficulty is overcome, and at the same time the measurement made by the observer is simplified by delaying the pulsing of one of the transmitters by an amount that is more than one half the pulse-recurrence interval from the other station. For example, the interval between a pulse from A and the next pulse from B is always made greater than the interval between the B pulse and the next A pulse. Thus the navigator can tell that the pulse followed by the longer interval is always from station A.

From the foregoing explanation it follows that many lines of position may be obtained. By selecting several time differences for a given pair of stations, the result is a family of hyperbolas like those shown in figure 5-16A. In this figure the pulses from both transmitters are identical and no time delay is introduced as indicated by zero on the center line.

In actual practice, one station of a loran pair (fig. 5-16B) is designated the master station. It establishes the Pulse Repetition Rate (PRR). The second, or slave station, receives the pulses of the master station and transmits its own pulses delayed in time but in synchronism with the master pulses. The time delay between the transmission of a pulse from the master station and the arrival of this pulse at the slave station depends chiefly upon the DISTANCE between the stations. This delay is caused by transit time.

After the pulse arrives at the slave station, there is a time delay of one-half the pulse-repetition period. This delay is necessary because of the two-trace method of cathode-ray-tube presentation at the loran indicator.

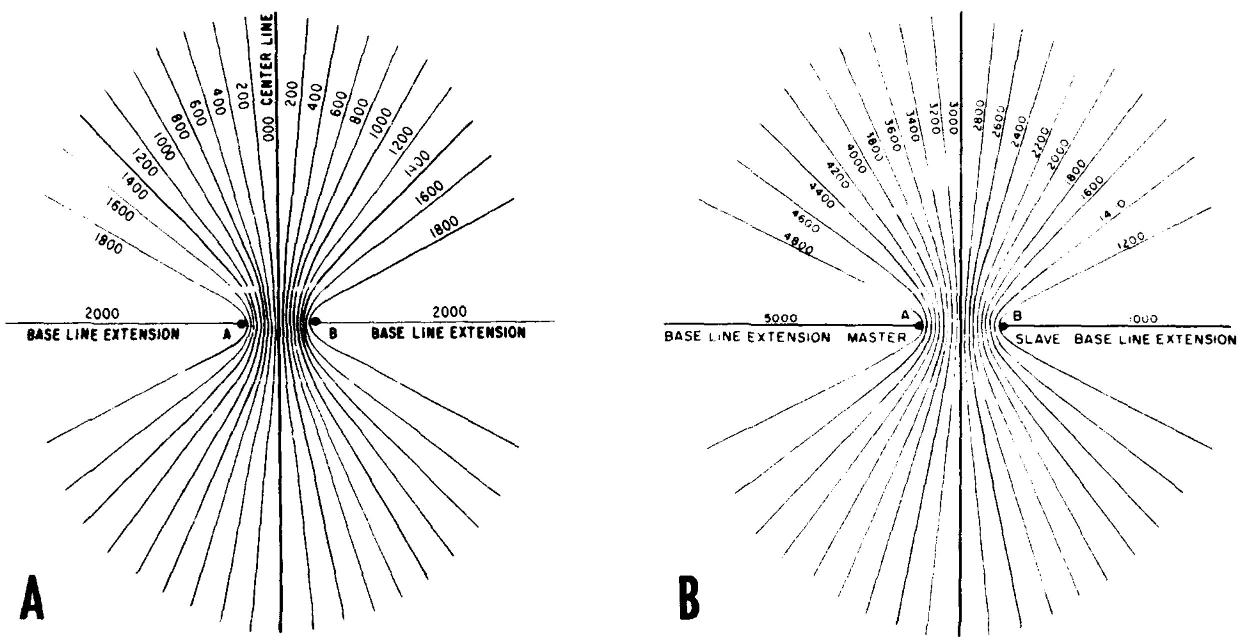


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Figure 5-16.—Lines of position.

In addition to these two delays, another delay, called the CODING DELAY, is added. The sum of the three delays is called the ABSOLUTE DELAY. The absolute delay is the time between the transmission of a pulse from the master station and the transmission of a pulse from the slave station. The absolute delay in figure 5-16, B, is 3000 μs, as indicated on the center line.

The PRR is different for different pairs of stations to enable the operator to identify the pair to which the receiver is tuned. There are four loran channels, numbered 1 through 4, corresponding to carrier frequencies of 1950, 1850, 1900, and 1750 kc, respectively. The BASIC PRR is either 25 cps (the LOW, or L, rate) or 33 1/3 cps (the HIGH, or H, rate). A third basic recurrence rate of 20 cps (the SPECIAL, or S, rate) is not in operational use, but is provided in new equipment to allow for expansion of the loran system.

The basic pulse recurrence rates are subdivided into SPECIFIC PRR. The specific low PRR is from 0 through 7, corresponding to 25 through 25 7/16 pulses per second in steps of 1/16 of a pulse per second. The specific high PRR is from 0 through 7, corresponding to 33 1/3 through 34 1/9 pulses per second in steps of 1/9 of a pulse per second.

To establish his position, the loran operator must have the proper loran charts, as well as the proper receiving equipment. A loran fix is the point of intersection of two lines of position. Two pairs of transmitting stations, or one master and two slave stations, are needed to establish the lines of position necessary for the fix. One pair of stations act as foci for one family of hyperbolas. The second pair of stations act as foci for another family of hyperbolas. As has been stated, a fix is the intersection of two hyperbolas, one from each family.

Figure 5-17 illustrates how a fix is obtained by using only one master and two slave stations. This is accomplished by causing the master station to transmit two distinct sets of pulses. The double-pulsed master station transmits one set of pulses at the PRR of the pulse transmitted by the first slave station and the other set of pulses at the PRR of the pulses from the second slave station.

Lines of position are identified by a letter and several numbers. The letter represents the basic PRR—Low (L), high (H), or special (S). The first number represents the channel (1 through 4), or carrier frequency; the second number denotes the specific PRR; and the last number is the time difference in microseconds. For example, 2L 6-2500 indicates channel 2, which is 1850 kc; a low basic PRR of 25 cps; a specific PRR of 6, corresponding to 25 6/16 cps; and a time difference of 2500 μs.

Loran charts for use aboard ships and aircraft are published by the U. S. Navy Oceanographic Office.

RADAR EQUIPMENT

Naval shipboard radar equipments are grouped into three general categories: search, fire control, and special. Search radars are further classified as surface search and air search. Fire control radars, integral parts of certain fire control systems, are used after targets have been located by search radars. Special radars are used for specific purposes such as recognition (IFF), ground-controlled and carrier-controlled approach, range rate, and height finding.

Radar operating principles are discussed in Basic Electronics, NavPers 10087 (revised). Representative radar sets and radar repeaters are listed below.

RADAR SETS

Radar Set AN/SPS-8B is a high-power, shipboard, height-finding radar system, designed for fighter aircraft direction. It presents target height, slant range, bearing, and beacon information on remote radar repeaters, Navy Model VK Plan Position Indicator (PPI), and Navy Model VL Range-Height Indicator (RHI).

Other height-finding radars that are either operational or being developed are AN/SPS-2, AN/SPS-13, AN/SPS-26, AN/SPS-34, AN/SPS-42, and AN/SPS-39A.

Table 5-3 presents information on operational search radars.

RADAR REPEATERS

In the early days of radar, indicators were a part of the console of the radar itself. However, with the increase in numbers and purposes of radar sets aboard ship remote indicators (radar repeaters) became necessary.

At the remote indicator, a selector switch permits the operator to select any one of the

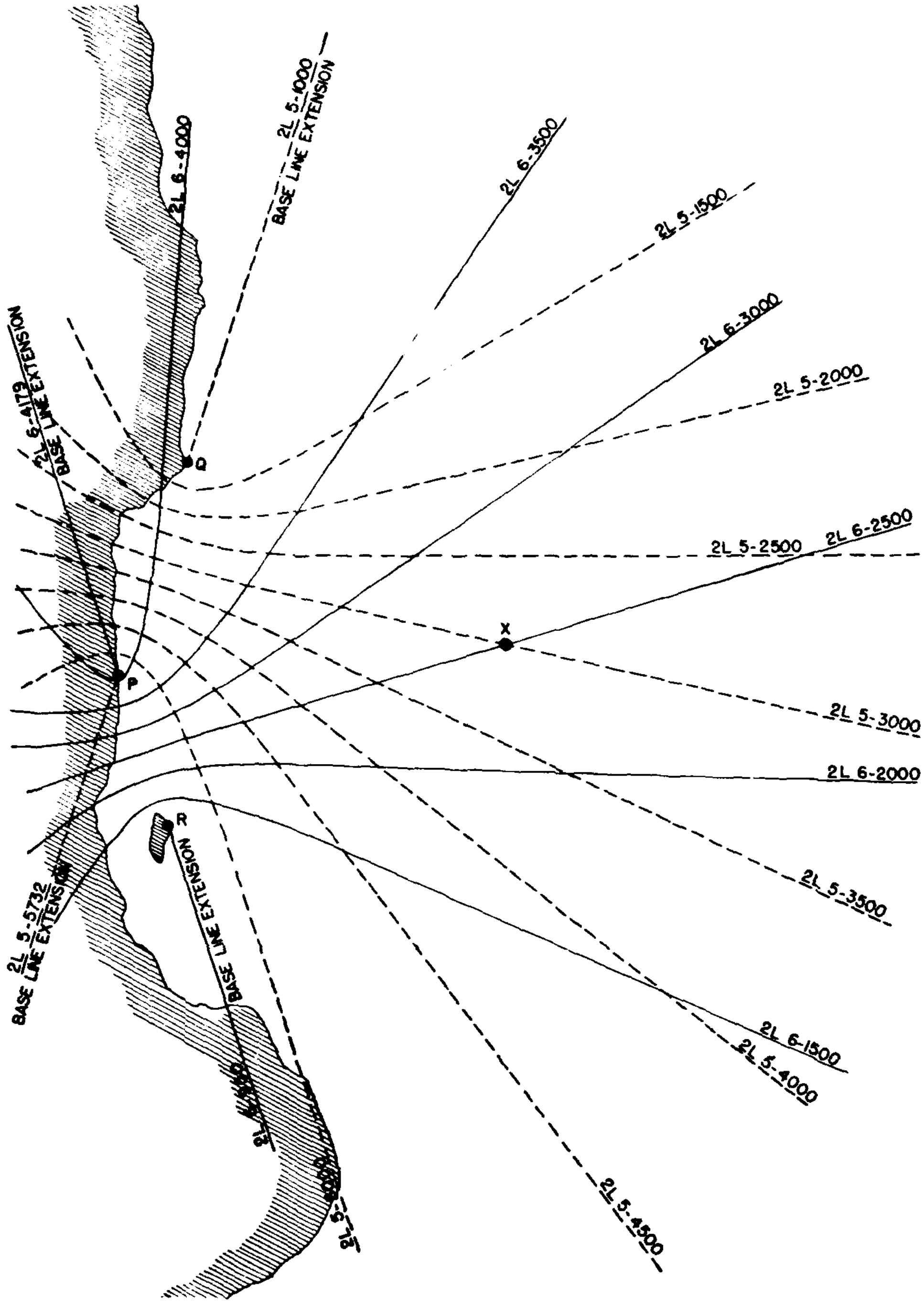

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Figure 5-17.—Obtaining a fix with one master and two slave stations.

Table 5-3.—Search Radars

Model	Type	Peak Power output	Use
AN/SPS-21	Surface Search	10 kw	Short range surface search on small craft, and as standby set on large ships.
AN/SPS-35	Surface Search	7 kw	Short range surface search—small craft.
AN/SPS-36	Surface Search	7-10 kw	Short range surface search—small craft.
AN/SPS-10	Surface Search	120-285 kw	Medium range surface search and limited air search—wide use on DDs and larger ships.
AN/SPS-12	Air Search	500 kw	Medium range air search—DDs and larger ships.
AN/SPS-28	Air Search	300 kw	Long range air search—DDs and larger ships.
AN/SPS-29	Air Search	750 kw	Long range air search—wide use on DDs and larger ships.
AN/SPS-37	Air Search	180 kw	Very long range air search—DDs and larger ships.

shipboard radar presentations for viewing. The output of the radar receiver is fed through an electronic network, which is separate from the main indicator circuit, and therefore the range scale used at the repeater does not have to be the same as that used at the main (console) indicator. A typical switching network is treated briefly in chapter 8 of this training course.

AN/SPA-8A Repeater

The AN/SPA-8A repeater may be used to display information from a variety of shipboard radars. When used with such radars, the PPI will be ship centered unless off-centering is introduced. Views of the top and front panels are shown in figure 5-18.

Provision is made on the indicator for an electronic cursor and range strobe. The electronic cursosr appears on the PPI as a sharp, bright line whose direction may be set by the BEARING CURSOR control. The range strobe is a bright spot that may be moved along the cursor by the RANGE STROBE control. Range and bearing may be read directly from counters. This information is made available in two synchro channels for transmission to remote points.

This repeater can be designed to be used as a part of the airborne early warning (AEW) system. This system extends the range of standard shipboard radar by carrying the search radar in a high-flying aircraft and relaying the radar information back to the ship for presentation on the ship's indicators.

Two indicators, one for tracking and one for use as a final indicator, may be used as a pair to display such relayed information. When used with the AEW system, the presentation on the tracking indicator will be AEW plane centered. The final (or repeat) indicator may present a display that is centered about the AEW plane, own ship, or any other point that is tracked on the tracking indicator. Ordinarily, in AEW applications, own ship will be tracked, thus causing an own-ship-centered display to appear on the final indicator, as illustrated in figure 5-19.

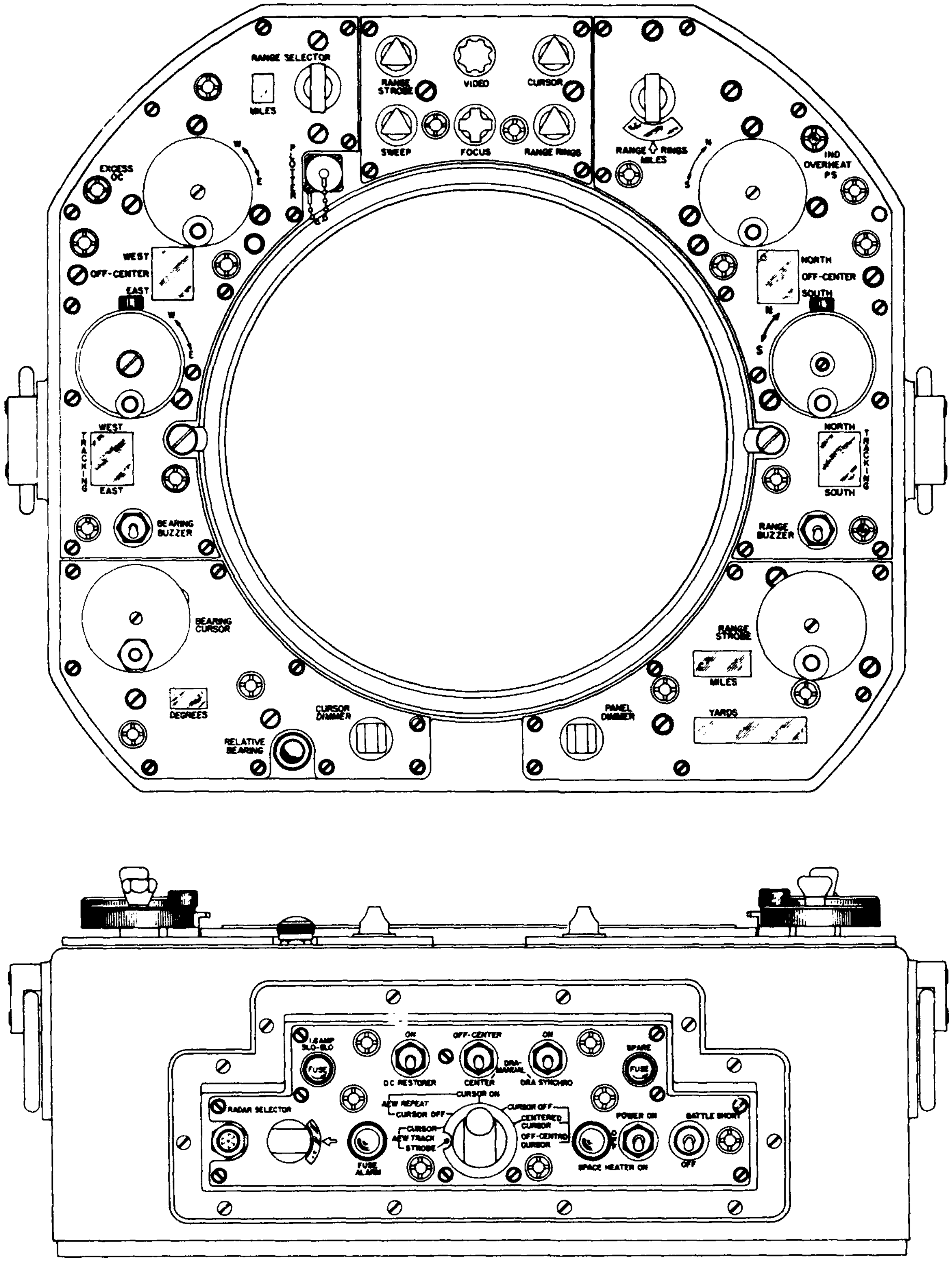

Figure 5-18.—Top and front panels of the AN/SPA-8A repeater.

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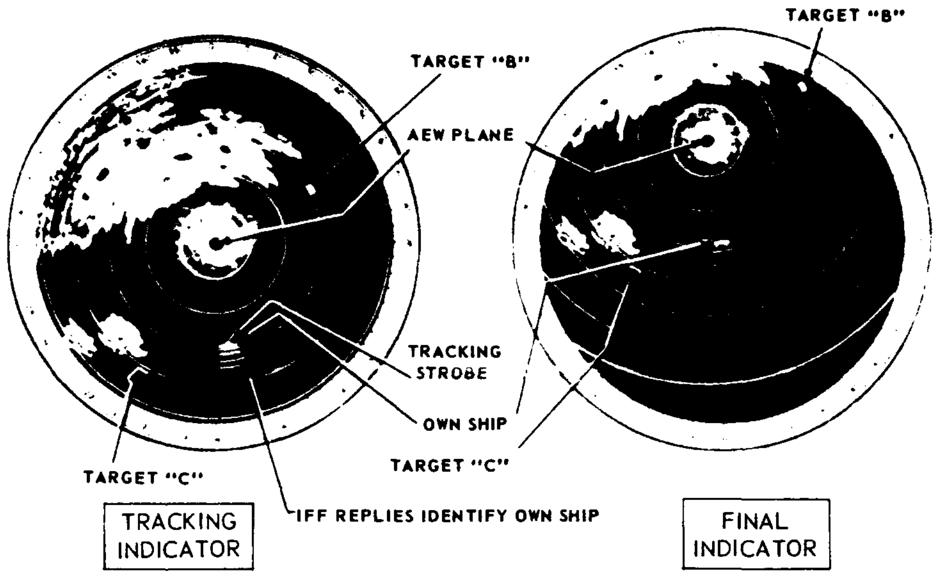

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Figure 5-19.—Ships presentation of AEW radar.

The display features may be listed as follows:

1. EXPANSION OF DISPLAY—The indicator is provided with a continuously variable sweep-speed control (rubber range control), permitting exact selection of the most useful range for any particular condition. It is often desirable to observe the radar display by the use of a short-range sweep. Close scrutiny of a target is permitted by expanding the display, and, if necessary, off-centering the display so as to keep the target on the screen. A fully expanded sweep yields a display in which the detail is limited by the radar, rather than by the PPI.

2. MANUAL OFF-CENTERING—The indicator is equipped with manual off-center controls, which permit displacement of the entire picture so that any target within a 250-mile range may be brought to the center (or any other region) of the display.

When using an expanded sweep, only a small portion of the area being searched by the radar is presented on the PPI. This small area may or may not include the particular desired target. To bring a desired target on the indicator, or to prevent the target from passing from view, manual off-centering may be introduced. By the use of both the expanded sweep and the manual off-centering, a remote target may be observed on a short-range display.

3. DRA OFF-CENTERING—The indicator has a synchro channel for receiving off-centering information from the ship's dead reckoning analyzer (DRA). This information is mechanically fed into the manual off-centering system of the indicator. DRA off-centering has the effect of cancelling the effects of own ship's motion, thereby presenting a stationary display. Such a display will show all targets, including own ship, moving in their true courses, and land masses will be fixed.

4. OFF-CENTER COUNTERS—There are two pairs of off-center counters (north-south and east-west) on the indicator. The counters show (in miles) how far the picture has been shifted from its centered position by the use of the off-center and the DRA.

5. TRACKING STROBE—When the AEW track strobe is used, a bright spot, known as the TRACKING STROBE, will appear on the display. This strobe may be moved about at will by means of the tracking controls, and may be caused to follow (track) any target that appears on the PPI. Synchro information regarding the position of this strobe can now be

furnished to remote points, specifically to a final (or repeat) indicator.

6. ELECTRONIC CURSOR—When the AEW track cursor is used, the origin of the bearing cursor on the indicator is not fixed at any point, but may be moved about so as to permit range and bearing to be taken between any two targets. When used in this manner, synchro data regarding the position of the origin of this roving cursor may be supplied to a final indicator just as though tracking were being performed with the tracking strobe. (Only one indicator at a time can be used for tracking.)

7. AEW OFF CENTERING—When an indicator is used as a final AEW repeater, a synchro channel is switched in for receiving off-center information from the tracking synchros of a tracking indicator. With such information, the location of the tracking strobe (or origin of the roving cursor) on a tracking indicator suitably wired to this indicator, will determine the location of the origin of the electronic cursor on the final indicator.

As many as five final indicators may be used with one tracking indicator without requiring auxiliary equipment.

AN/SPA-4A Repeater

The Range-Azimuth Indicator AN/SPA-4A (fig. 5-20) displays information supplied by ship's radar systems with pulse repetition rates between 60 and 3000 pulses per second. The information is displayed on a 10-inch cathode-ray tube PPI.

The PPI sweep is rotated in synchronism with the associated radar antenna by means of a servosystem. The cursor sweep can be rotated by a handcrank to any desired radial location. A spot of light (the range strobe), appearing on the cursor sweep may be superimposed on any target in the PPI display. The location of the range strobe may be changed by rotating either the range handcrank or the bearing handcrank or both.

The range and bearing of the range strobe (and hence the position of a particular target) is registered on mechanical counters. This information may also be repeated at remote points throughout the ship.

VK Repeater

The VK repeaters have been improved through a series of changes. The VK-5 functions as a standard PPI repeater, off-center PPI repeater, or expanded off-center PPI repeater. It may be used on shore, shipboard, or submarine. It presents AEW and DRA information and designates selected targets to remote PPI repeaters.

Target ranges may be estimated with fixed range markers or with a dial-controlled range ring. Target bearing may be measured on a dial around the rim of the PPI presentation with the aid of a mechanical cursor, or it may be measured with either a screen-centered, display-centered, or wandering electronic cursor.

Off-center presentation may be used to increase the effective screen area and to display targets from AEW aircraft or a DRA relay receiver. The start of the PPI sweep may be shifted off center in any direction by manual means to locate the observer's ship on the center of the PPI screen. After initial off-centering, displays are automatically off-centered in AEW or DRA operation.

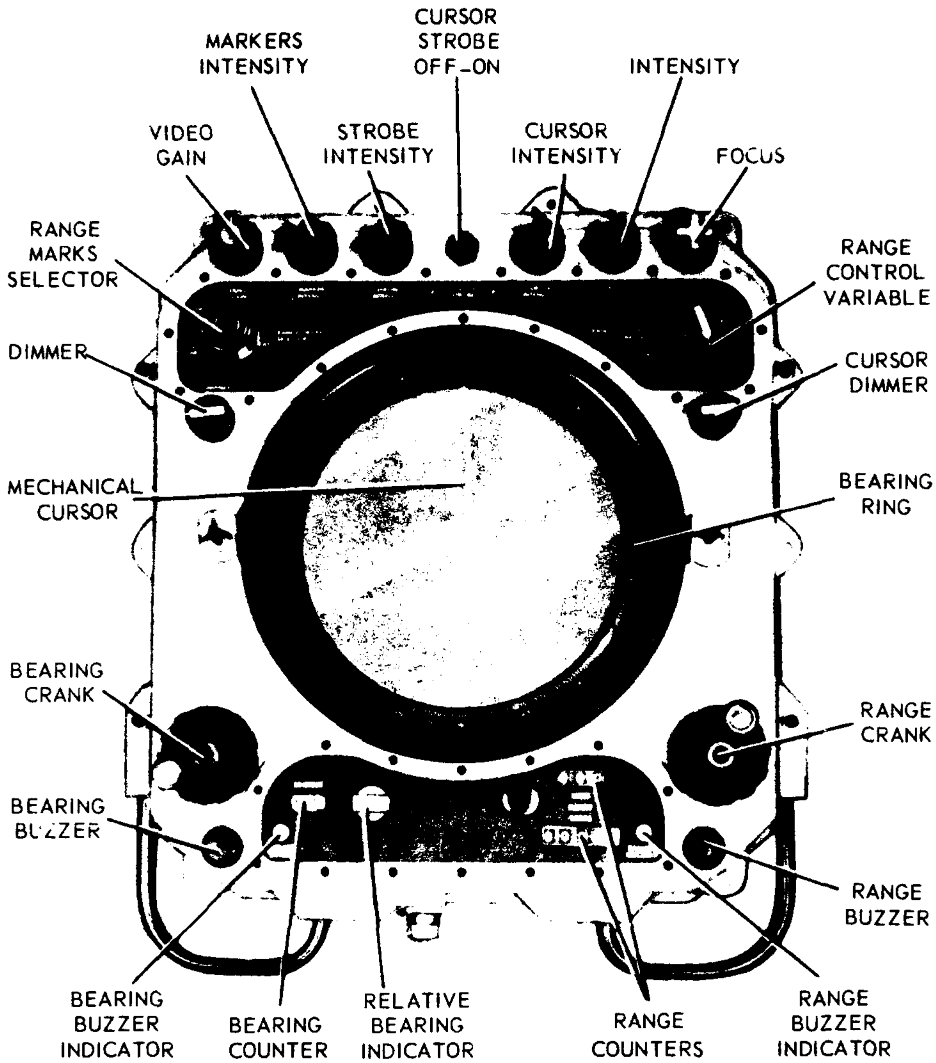
VL Repeater

The VL-1 repeater is a remotely controlled range-height indicator designed to repeat information obtained from any standard Navy height finding radar system. The scope displays patterns within ranges of 20, 40, 70, and 140 miles (the ranges can be changed to 20, 40, 100, and 200 miles, if desired).

The screen display forms a roughly rectangular area, with the trace originating at the lower left-hand corner of the display. Targets appear as bright spots on the screen. Height is shown vertically, and range is shown horizontally.

In operation, four equally spaced electronic range marks appear on the screen as bright, curved lines (arcs of concentric circles) associated with each range. These lines appear on their respective ranges as 5-, 10-, 20-, and 50-mile range markers.

The height of a selected target is measured by means of a mechanically controlled electronic height marker appearing as an approximately horizontal line across the scope screen. The height line is raised or lowered by a handwheel until it intersects the bright spot representing the selected target. The height of the target, in feet, is then read from a height counter.



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Figur 20.—Radar repeater AN/SPA-4A.

IFF EQUIPMENT

An electronic system has been developed that permits a friendly craft to identify itself automatically before approaching near enough to threaten the security of other naval units This system is called identification, friend or foe, or IFF. It consists of a pair of special transmitter-receiver units. One set is aboard the friendly ship and the other is aboard the friendly unit (ship or aircraft). Because space and weight aboard aircraft are limited, the airborne system is smaller and lighter (and requires less power) than the shipboard transmitter-receiver. The airborne equipments are automatic and do not operate until triggered by a signal from a shipboard unit.

IFF systems are designated by MARK numbers. In order to avoid confusion between IFF systems and fire-control systems, the IFF

mark number is a Roman numeral (Mark III); whereas, the fire control number is an Arabic numeral (Mark 29). The IFF system operates as follows: An air-search radar operator sees an unidentified target on his radar scope. He turns on the IFF transmitter-receiver, which transmits an INTERROGATING, or "asking," SIGNAL to the airborne transmitter-receiver. The interrogating signal is received by the airborne unit, which automatically transmits a characteristic signal called an IDENTIFICATION SIGNAL. The shipboard system receives the signal, amplifies it, and displays it on the radar scope, or on a separate indicator scope. When the radar operator sees the identifying signal and identifies it as the proper one, he knows that the aircraft is friendly.

However, if the aircraft does not reply when interrogated, or if it sends the wrong identifying signal, the ship must then assume that the target is an enemy, and defensive action must be taken. IFF equipments comprise (1) the interrogator-responsor, and (2) the identification set (transponder).

The interrogator-responsor performs two functions: transmits an interrogating signal, and receives the reply. The transponder also performs two functions: receives the interrogating signal, and replies automatically to the interrogating signal by transmitting an identifying signal. The two types of interrogation are DIRECT and INDIRECT. The interrogation is direct when the interrogating signal that triggers the transponder is a pulse from the radar equipment. The interrogation is indirect when the interrogating signal is a pulse from a separate recognition set operating at a different frequency from that of the master radar.

Early IFF systems used direct interrogation. However, direct interrogation proved unsatisfactory because the transponder was required to respond to radars that differed widely in frequency. Therefore, the later IFF systems make use of indirect interrogation within a special frequency band reserved for IFF operation.

ANTENNA STABILIZATION DATA EQUIPMENT

Stabilization Data Set AN/SSQ-14 is a vital link in establishing a stabilized antenna platform. It supplies a synchro signal indication of the angular displacement of the ship's deck with respect to the horizontal as the ship pitches and rolls. Two gyro units, one associated with pitch and the other with roll, are mounted on a horizontal platform with their output axes vertical. The outputs of these gyro units, with their associated servoloops, maintain this platform in a horizontal position. The pitch and roll angular correction is sent to the desired destination (the system that keeps the radar antenna stabilized, for example) by means of transmitting synchros geared to the pitch and roll axes of the stabilized platform.

Other equipments furnishing stabilization data (roll and pitch signals) are the AN/SSQ-4, Stable Elements Mk 8 Mods 2 and 4, and the Sperry Mk 19 gyrocompass.

COUNTERMEASURES

For the purpose of a brief description of countermeasures, this chapter treats the subjects under the two general headings; electronic countermeasures and nonelectronic countermeasures.

ELECTRONIC COUNTERMEASURES

Electronic countermeasures (ECM) may be classified as ACTIVE or PASSIVE. Passive ECM is the use of receiving equipment to intercept enemy radar or radio transmissions. Active ECM is the use of transmitting equipment that may be used to jam the enemy transmissions.

In order to use countermeasures most effectively against an enemy radar, as many as possible of the following characteristics should be known about the enemy radar facility: (1) the frequency, pulse width, pulse-repetition frequency, and peak power of the transmissions; (2) the receiver bandwidth and the time constants of the receiver coupling circuits; (3) antijamming features; (4) amount of shielding; (5) type of indicator; (6) antenna beamwidth; (7) types of scan; and (8) use of the radar.

Likewise, in order to use countermeasures most effectively against enemy communications systems, the following information is needed: (1) the frequency of transmissions, (2) type of modulation, and (3) receiver bandwidth.

Some of the foregoing information is obtained by analyzing the enemy transmission, and the other information may be obtained by examining captured equipment.

Special equipment has been developed for use in analyzing r-f transmissions. This equipment includes SEARCH RECEIVERS, which search the various frequency bands for the various types of emissions; PANORAMIC ADAPTERS, which measure the frequency, strength, and type of modulation of a transmission in a selected band of frequencies; and PULSE ANALYZERS, which measure the pulse rate and width. The pulse analyzer and the panoramic adapter are used with the search receiver.

NONELECTRIC COUNTERMEASURES

Units called CORNER REFLECTORS are used to present strong echoes to enemy radars. When suitably placed, they return strong echoes that appear to the enemy radar operator as a large naval force. Corner reflectors have other valuable uses also. For example, they can be used on liferafts to assist friendly search radar to locate them.

ROPE is the code name for long streamers of aluminum foil. This foil, cut in lengths of about 400 ft., is dropped by aircraft within range of an enemy radar. The twisting and turning of the foil as it falls presents many different effective lengths to the enemy radar. Some of these lengths are highly resonant at the frequency of the radar, and therefore appeared as strong target signals.

WINDOW is the code name for short strips of aluminum foil. The foil is cut to slightly different lengths so that it causes strong reflected signals at the frequency of the enemy radar. The strips are packaged and dropped over enemy territory. While fluttering to the ground, they present a multitude of targets to the enemy radars. Thus, enemy search and tracking radars follow the strong echoes presented by the window and find it difficult to track on the lesser echoes presented by the aircraft.

DECOYS consist of a wide variety of devices. Some of the most effective are balloons towing strips of aluminum foil. These strips, which vary in length, present strong reflections over a fairly wide band of frequencies. Other decoys are aircraft towing streamers of foil. Corner reflectors might also be considered decoys.

Antijamming measures, or counter-countermeasures (CCM), are used to reduce the effect of enemy jamming on our own equipment. In receivers some of the most important CCM devices are special filters that pass only the most important parts of echo signals, thus rejecting as much of the jamming signal as possible. In the transmitters, a great many radar equipments have tunable magnetrons whose frequency may be varied at intervals to prevent an enemy jamming transmitter from locking on the radar signal.

TIMING CIRCUITS

In many of the previously mentioned electronic installations aboard ship, timing circuits are an important part of the operation. For example, timing circuits are used in radar, loran, multiplex communications systems, closed circuit television, facsimile transmissions and electronic countermeasures. One application of timing circuits is that of multivibrators as electronic swiching devices (ring counters in multiplex system) and multi-signal inputs in cathode ray displays. An electronic switch enabling the simultaneous display of two waveforms on a cathode ray oscilloscope screen is described in Basic Electronics NP 10087 (revised). This circuit employs triode electron tubes that are periodically cut off so that a grid signal may not be transmitted. The signal is transmitted through the triode only during the period that the gating signal renders the tube in a conduction condition. This is a form of coincidence circuit that produces an output only when the gating signal on the cathode coincides in time with the input signal on the grid. Coincidence circuits are treated in more detail in advanced training courses.

EQUIPMENT INSTALLATION

The location of units of electronic equipment is normally governed by an installation plan. The installation is planned to ensure maximum efficiency of the electronic system as a whole—within the limitations imposed by a particular vessel.

The work of the ET is made easier when there is sufficient space to remove panels or chassis for adjustments and maintenance, and the electronic equipment spaces are well ventilated.

Equipments are installed on foundations or racks that are attached to the deck or bulkhead or a combination of both. Often it is necessary to make additional provisions for shock mounting

the equipment. Adequate grounding should be made to the ship's structure according to the latest BuShips instruction.

EQUIPMENT FOUNDATIONS AND RACKS

Foundations and racks are constructed from appropriate metal shapes, and they are generally of all-welded construction. A rack using a combination of deck and bulkhead for support is illustrated in figure 5-21,A. A deck foundation is illustrated in part B.

Bulkheads that are inadequately stiffened or subjected to direct stresses and shocks caused by gun blasts, explosions, etc are not normally used to support electronic equipment containing vacuum tubes, relays, and geared mechanisms. Under these conditions these units are generally deck mounted or installed on suitable deck-mounted racks.

Adequate equipment-to-bulkhead clearance is necessary on all deck-mounted electronic equipment to provide space for shock-mount movement, ventilation, and servicing.

Tall and heavy units normally require that top foundations be used in addition to the regular deck foundations (fig. 5-22,A). A center-of-gravity mounting has four mounting points at diagonally opposite corners, and the plane of these points passes through or near the center of gravity of the unit, as illustrated in part B. When the equipment is low, a four-point bottom mounting (part C) may be adequate.

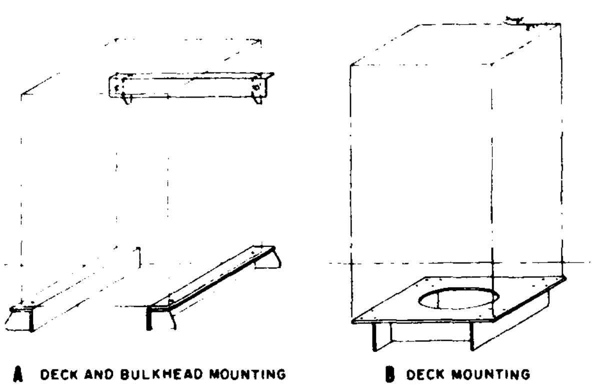

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Figure 5-21.—Deck and bulkhead foundations.

SHOCK MOUNTS

Shock mounts are used to protect equipment from the severe shock encountered in naval shipboard service. Most equipments are supplied with shock mounts by the manufacturer of the equipment, if required. There are several types of rubber shock mounts, but they all serve essentially the same function.

One type of shock mount, showing the method of grounding the equipment, is illustrated in figure 5-23.

In addition to the clearances required for the equipment, a clearance for the mount itself must be taken into consideration. The clearance in the direction perpendicular to the bolt axis should be at least equal to the thickness of the wall of rubber contained in the mount. Sufficient clearances around the equipment must be maintained so that motions due to shock do not cause the equipment to strike adjacent structures.

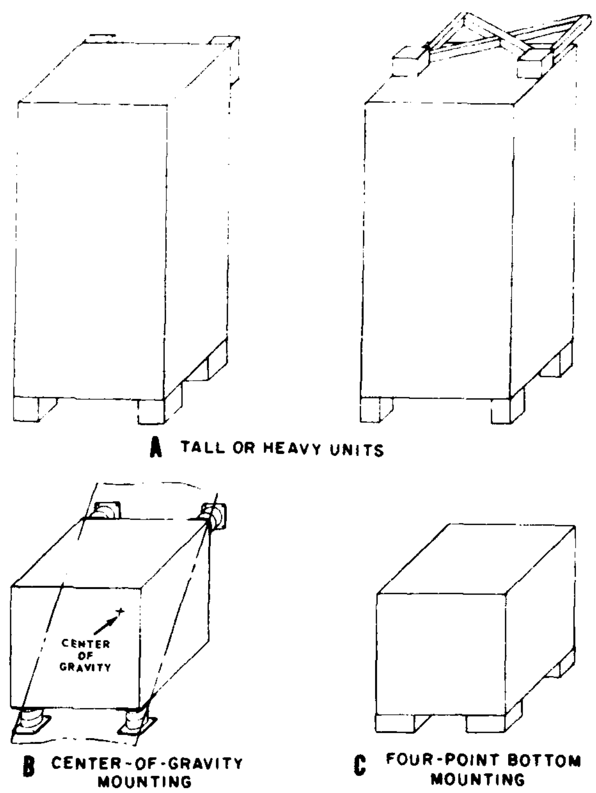

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Figure 5-22.—Unit installations.

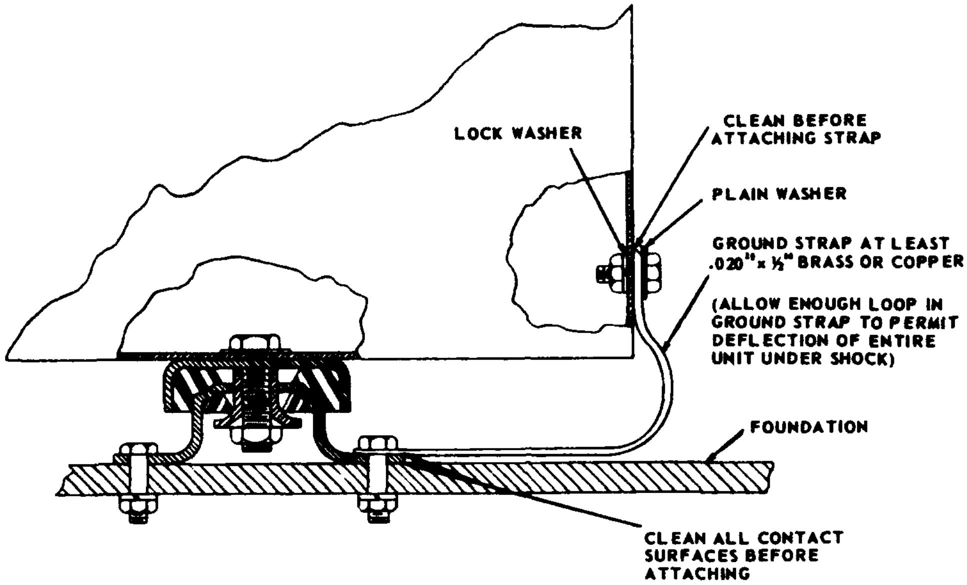

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Figure 5-23.—Shock mount and method of grounding the equipment.

GROUNDING ELECTRONIC EQUIPMENT

The proper grounding of electronic equipment is one of the most important steps in the installation procedure. During routine checks, tests should be made to ensure that all equipment is properly grounded.

All units of electronic equipment whose d-c resistance from case to ground exceeds 0.01 ohm (10 milliohms) are grounded by straps as follows:

1. On units requiring sound isolation, copper braid, not less than one-half inch wide is used.
2. On other units, not less than 0.020-inch by 1/2-inch sheet copper or brass is used.
3. The surfaces at the point of attachment of the straps are thoroughly cleaned to ensure metal-to-metal contact.
4. The straps are made as short as possible with only enough loop allowed to permit satisfactory deflection of shock or isolation mounts.
5. The strap connections are locked to prevent loosening from vibration.
6. Only one strap is used for each unit unless tests indicate more are needed.

Proper grounding is equally as important for shielded cables and other components as it is for electronic equipment.

TYPES OF CABLES

The various electrical and electronic systems aboard ship depend on power supplied by the ship's service generators. This power is distributed to the equipment by a system of cables. Power cables are normally installed by shipyard forces, but the ET should know the location and characteristics of the cabling, which supplies the electronics equipment.

He should become familiar with the current-carrying capacity of cables; their insulation strength; and their ability to withstand heat, cold, dryness, bending, crushing, vibration, twisting, and shock. Several types of cables are used in the applications under discussion, with design characteristics suited to their location and purpose.

Type SGA (Shipboard, General use, Armored) cables are designed to have a minimum diameter and weight consistent with service requirements in fixed wireways on naval ships. This type supersedes the older, widely used type HFA (Heat and Flame resistant, Armored) cable.

Type SSGA cable (fig. 5-24) consists of stranded copper conductors (in this case, only one conductor—indicated by the "S" before SGA) insulated with silicone rubber and glass fibers around which is placed an impervious

sheath. The sheath is covered with braided metal armor, and then a coat of paint is applied.

The SGA cables are designated as follows: (1) SSGA, single conductor; (2) DSGA, twin (double) conductor; (3) TSGA, three conductor; and (4) FSGA, four conductor.

The HFA cables (also composed of stranded copper conductors) are designated as follows: (1) SHFA, single conductor; (2) DHFA, twin (double) conductor; (3) THFA, three conductor; (4) FHFA, four conductor; and (5) MHFA, multiconductor.

Twisted-pair telephone cables are designated as TTHFWA.

Many applications aboard ship require cables that can be bent and twisted again and again without damaging the conductor insulation or the protective covering. For such applications, flexible cables are used.

Flexible cables have synthetic rubber or synthetic resin insulation and a flexible sheath that is resistant to water, oil, heat, and flame. However, these cables are not as heat and flame resistant as armored HFA and SGA cables. Flexible cables for general use are designated by the letters, HOF—for example, DHOF, THOF, and FHOF. Flexible cables for limited use are designated by the letters COP—for example, DCOP, TCOP, and FCOP.

Other types of cables used in electronics work are:

1. DRHLA—Double conductor, radio, high-tension, lead armored.
2. FHFTA—Four conductor, heat and flame resistant, thin-walled armor.
3. MCSP—Multiple conductor, shielded, pressure resistant (submarine applications).
4. TTRSA—Twisted-pair telephone, radio shielded, armored (characteristic impedance approximately 76 ohms).

Designation of Conductor Size

Generally, when the size of the individual conductors contained in the cable is indicated in the cable designation, the numeral (or numerals) following the letter designation indicate the approximate cross-sectional area of the individual conductors in thousands of circular mils to the nearest thousands. For example, TSGA-60 is a 3-conductor armored cable for general shipboard use, with each conductor having a cross-sectional area of 60,090 circular mils. However, when the numerals immediately following the letter designation indicate the number of conductors comprising the cable, the size of the individual conductors may be indicated by additional numerals enclosed in parenthesis. For example, MDGA-19(6) is a 19-conductor electrical power cable for shipboard nonflexing service, with each conductor having a cross-sectional area of 6,512 circular mils.

Multiple-Conductor Designations

Multiple-conductor cable types and class designations are followed by a number that indicates the number of conductors. For example, MSCA-30 is a heat and flame resistant armored cable with 30 conductors.

For telephone cable, the number indicates twisted pairs. For example, TTHFWA-25 means that the cable contains 25 twisted pairs; TTRSA-4 means that the cable contains 4 pairs individually shielded.

Tagging Cables

Ship's cables are identified by metal tags (fig. 5-25) that give information about the cable. Permanently installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located within a single compartment in such a manner that they can be readily traced are not tagged. Past practice was to use colored tags to classify vital, semivital, and nonvital cables. This practice

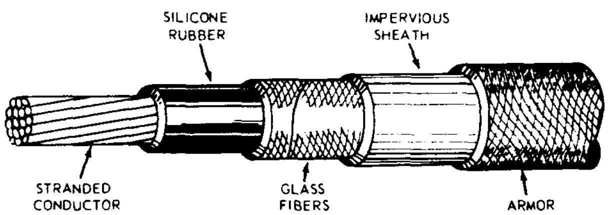

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Figure 5-24.—SSGA cable.

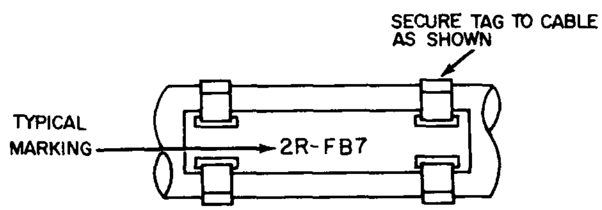

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Figure 5-25.—Cable tag.

has been discontinued, however colored tags will still be found on some ships.

Power and lighting cables are tagged as specified in article 60-270 of the Bureau of Ships Technical Manual. Cables between units of electronic equipment are tagged with electronics designations (table 5-4). For example, in figure 5-25, the 2R-ES indicates the second surface search radar circuit on the ship, R indicates electronics, ES indicates a surface-search radar circuit, and 7 indicates cable number 7 of the surface search radar. Electronics Information Bulletin #578 contains additional information concerning electronics designations.

SELECTION AND INSTALLATION OF POWER CABLES

The ET 3 will, in all probability, not be called upon to select and install power cables. However, he should have some knowledge of the power cables in the electronics spaces. There are at least five items that must be considered when power cables are installed. They are (1) the maximum connected load in amperes, (2) the possible added load due to future installations, (3) the demand factor (that is, the average demand in amperes over a 15-minute interval divided by the total connected load in amperes), (4) the cable service rating (the physical characteristics required for a given type of service), and (5) the maximum allowable voltage drop in the part of the circuit under consideration.

The current-carrying capacity and voltage-drop limitations determine the cable size for a particular application. The current capacity is dependent upon the type and size of the conductor, the permissible temperature rise, and the physical characteristics of the space in which the cable is installed. The allowable voltage drop depends on the type of load connected to the circuit.

All connections to cables are made in standard appliances and fittings; splice connections are not made. However, cable splices are permitted as an emergency repair (by ship's force), and on a limited basis (by repair activities) where it has been determined that time and replacement cost is excessive, and existing cable is in good condition. Cables entering watertight equipment are brought into the equipment through stuffing tubes. Stuffing tubes are also used where cables pass through decks and watertight bulkheads. Cables passing through decks are protected from mechanical injury by kick-pipes or riser boxes.

Table 5-4.—Electronics Circuit or System Designations.

Circuit or system designation	Circuit or system title
R-A	Meteorological
R-B	Beacons
R-C	Countermeasures
R-D	Data
R-E	Radar
R-F	Fire control radar
R-G	Electronic guidance remote control or remote telemetering.
R-H	CW passive tracking
R-I	IFF equipment
R-K	Precision timing
R-L	Automatic vectoring
R-M	Missile support
R-N	Infrared equipment
R-P	Special purpose
R-R	Radio communication
R-S	Sonar
R-T	Television

Two types of stuffing tubes are illustrated in figure 5-26. The type shown in part A is designed to be installed in the wall of an electrical appliance or fitting to permit the insertion of an electric cable. The cable is

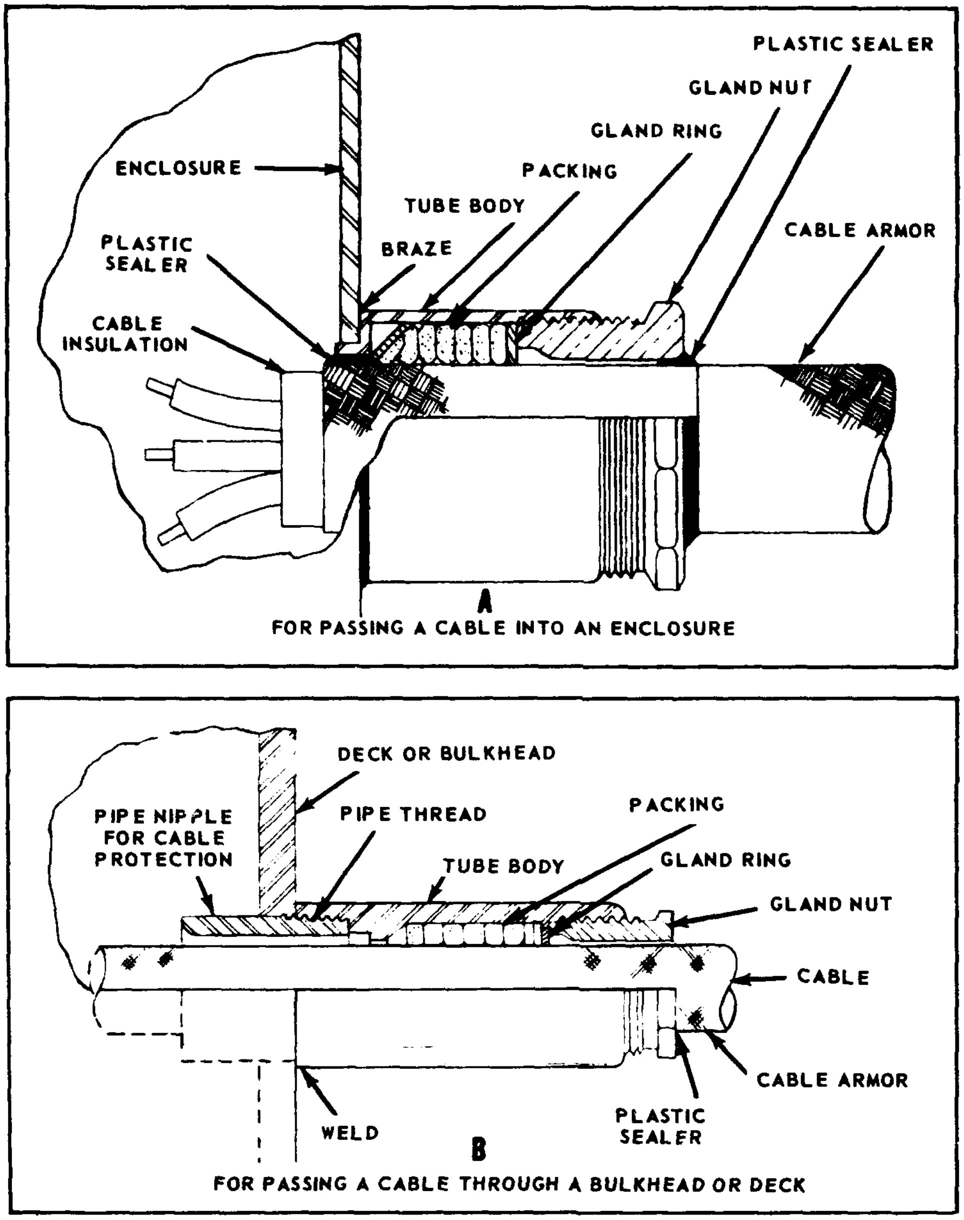

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Figure 5-26.—Types of stuffing tubes.

terminated in the appliance. The type shown in part B is designed to be installed in a deck, bulkhead, or hull to permit an electric cable to be passed through the structure. The cable is not terminated after passing through the tube but continues to some distant point.

Both types of stuffing tubes are forms of packing glands and serve a common purpose in preventing the passage of liquids and gases at the point of cable entrance.

A kickpipe is a pipe used to pass cables through decks wherever cable protection from

mechanical injury is needed. A kickpipe assembly is illustrated in figure 5-27. The minimum length of a kickpipe is nine inches and the maximum length depends on the requirements. If the length of the kickpipe is over twelve inches, the top is secured by a brace.

More recently, nylon stuffing tubes have been developed by the Bureau of Ships. These stuffing tubes are extremely durable and are used where practicable.

Specific information on the installation of stuffing tubes and kickpipes is included in chapter 8 of the Electronic Installation Practices Manual, NavShips 900,171.

CONSTRUCTION AND INSTALLATION OF R-F CABLES

R-f cables may look like power cables, but they require special handling and careful installation. These cables are vital to the proper operation of all electronic equipment and therefore must be installed and maintained with the greatest care.

Construction

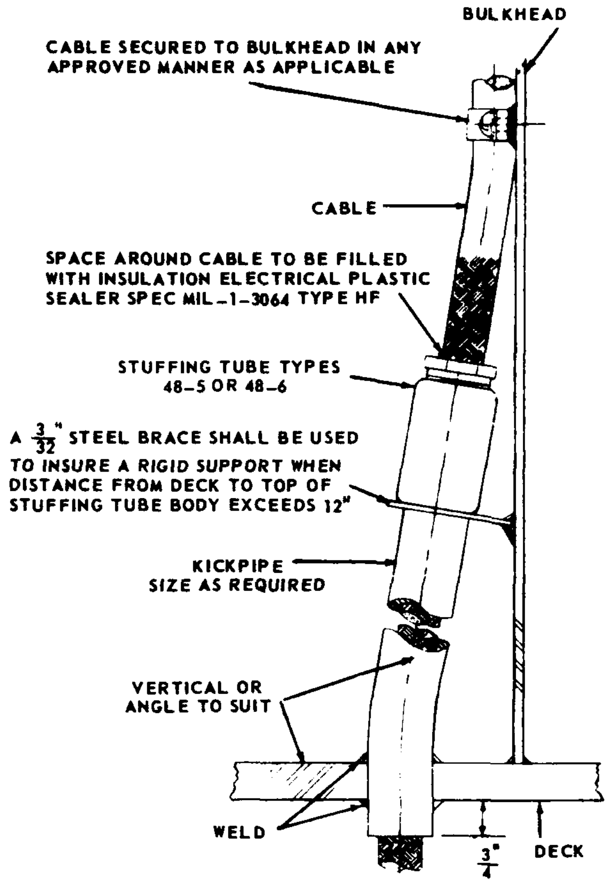
Flexible radio-frequency transmission lines (coax) are two-conductor cables, one conductor of which is concentrically contained within the other, as illustrated in figure 5-28. Both conductors are essential for efficient operation of the transmission line. The proper connectors and terminations are also necessary for efficient operation of the line.

The inner conductor may be either solid or stranded and may be made of unplated copper, tinned copper, or silver-plated copper. Special alloys may be used for special cables.

The dielectric insulating material is usually polyethylene or teflon, although neoprene or other rubber-like materials are occasionally used for pulse cables. (Pulse cables carry d-c pulses that may have relatively high voltages during a relatively short pulse time.)

Braided copper is usually used for the outer conductor; it may be tinned, silver plated, or bare. The outer conductor is chosen to give the best electrical qualities consistent with maximum flexibility.

The protective insulating jacket is usually a synthetic plastic material (vinyl resin). Neoprene rubber is generally used on pulse cable; silicone rubber jackets are used for high-temperature applications.



70.25

Figure 5-27.—Kickpipe assembly.

Armor is needed for protection. It may be braided aluminum, or sometimes galvanized steel, similar to that used on power cables.

Polyethylene is a gray, translucent material. Although it is tough under general usage, it will flow when subjected to heavy pressure for a period of time. Two possible effects of bad installations are illustrated in figure 5-29.

Teflon is a white opaque plastic material. This material will withstand high temperatures and will remain flexible at relatively low temperatures. It has a peculiar quality in that nothing will stick to it and it is unaffected by the usual solvents.

Synthetic rubber (neoprene) is black and very flexible. It has high power loss at high frequencies and therefore is not used in cables carrying r-f energy. However, it is used for

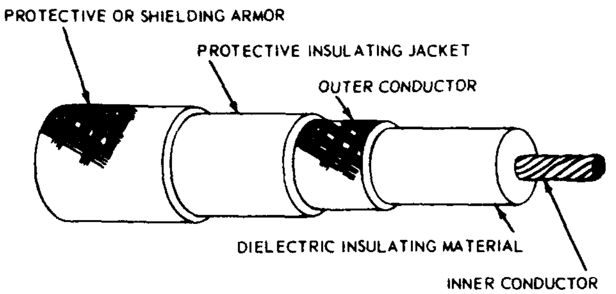


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Figure 5-28.—Construction of flexible r-f transmission line.

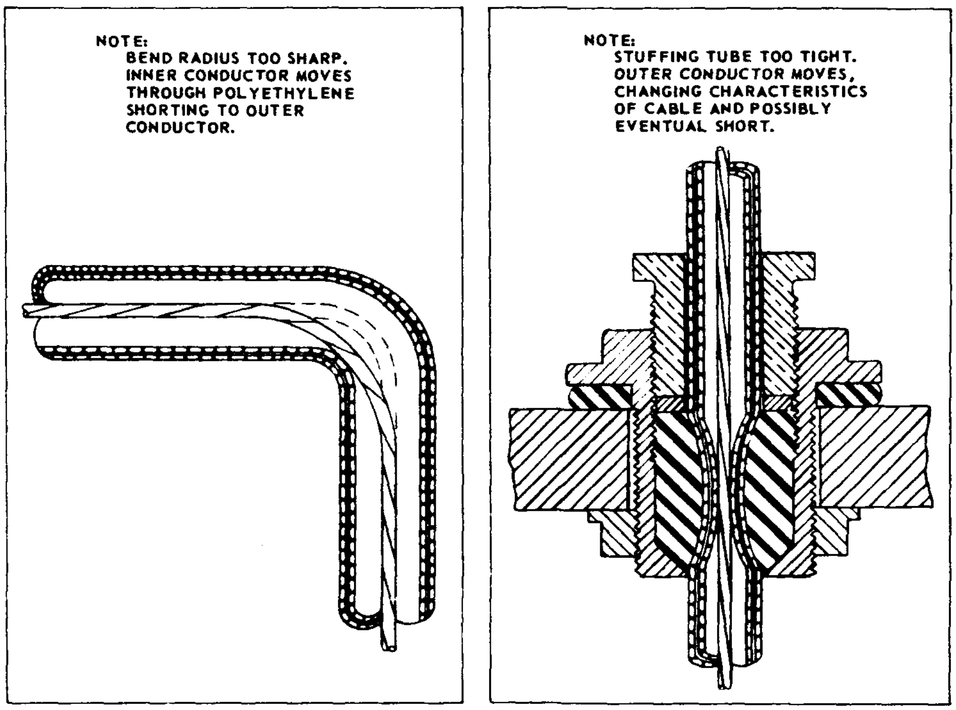
transmitting high-voltage d-c pulses. Because of its flexibility and ability to "stick" to metals, it forms very tightly around the conductors and minimizes corona (high-voltage breakdown of the air surrounding a conductor).

Location and Length of Cable Runs

When possible, cables are run along different well separated paths to reduce the probability of battle damage to several cables simultaneously. Wherever possible, high-temperature locations are avoided. Pulse cables are run separately, when possible, to reduce coupling and interference.

Because attenuation (power loss) in a line increases with its length, cables are kept as short as practicable, consistent with avoiding high-temperature locations, sharp bends, and strain on the cable.

If the equipment is shock mounted, enough slack in the cable is allowed to permit unrestricted motion of the equipment. The cable may be wrapped with friction tape for a distance of three or four inches from a point under the last cable clamp in the direction of the equipment. This eases the bending of the cable at the point and reduces the possibility of cable deformation because of constant vibration.



1.44
Figure 5-29.—Effects of bad installations.

When cables are connected to equipment that slides out for maintenance, extra slack is provided.

Installing the Cables

Flexible cables are flexible only in the sense that they will assume a relatively long bend radius. They are not intended to be stretched, compressed, or twisted; and they are installed with this in mind. Bends are made as large as practicable, the minimum radius of bend being 10 times the diamater of the cable.

The number of connectors are generally kept to a minimum to reduce line losses and maintenance problems.

Fabricated straps are used for holding the cables. They are snug, but not too tight. Back straps (which keep the cable away from a surface) are used in making cable runs along masts or in compartments that are subject to sweating. In more recent installations semicontour straps and cable bands are used for certain applications.

The exact methods of installing cables are included in the Electronics Installation Practices Manual, NavShips 900,171.

In addition, the Cable Comparison Guide, NavShips 250-660-23, contains information pertaining to all types of electric shipboard cable.

RIGID R-F TRANSMISSION LINES

Rigid r-f transmission lines include waveguides (rigid and flexible), bead-supported coax (teflon and steatite), stub-supported coax, and pyrotenax cable.

Rigid waveguides may be round or rectangular in shape; however, the use of round waveguides is limited to special applications, such as rotating joints. Rectangular waveguides are widely used in radar applications. Waveguides are generally designated by size. Table 5-5 lists some of the more common sizes.

Flexible waveguides have greater power loss than rigid waveguides, and therefore the flexible type is seldom used except where there is considerable vibration.

Bead-supported coax was used on early radar equipment installations and is still necessary in certain types of installations.

Stub supported coax was more widely used on early radar equipment installations; and short runs are still found in late equipments, usually within the antenna pedestal.

Pyrotenax coax r-f cables have a solid copper inner conductor, a seamless copper outer conductor, and a tightly packed powdered magnesium oxide dielectric. They are fireproof and pressure proof, and are designed for installations where these properties are important.

The proper type and size of waveguide is determined by the equipment designer, and no change is made without the approval of the Bureau of Ships.

Many factors are considered when a waveguide is installed. However, two of the most important considerations are: (1) the range of the equipment depends on the height of the antenna and (2) a great deal of energy is lost when the length of the waveguide is increased by a small amount (over one-half of the power may be lost in a 50-ft run).

The method of installation is equally important. For example, sharp bends, dents, and foreign materials in the guide will cause serious attenuation of the signal.

From these considerations it may be seen that there is an optimum height beyond which additional waveguide length will defeat its own purpose.

Rigid r-f transmission lines are discussed in detail in chapter 11 EIPM-NavShips 900171.

Table 5-5.—Commonly Used Sizes Of Rigid Waveguides.

Size (inches)	Radar Band	Frequency Band
6 1/2 x 3 1/4	L	UHF
3 x 1 1/2	S	UHF/SHF
1 1/4 x 5/8	X	SHF
1 x 1/2	X (small)	SHF
5/8 x 5/16	K	SHF/EHF

ANTENNA SYSTEMS

One of the most important functions performed aboard ship is that of communicating with other ships or stations; and one of the most important links in a communication chain is the antenna system. The following paragraphs are included to give the prospective ET 3 information about shipboard antennas and antenna transmission lines.

Wire Antennas

The whip and dipole antenna assemblies are greatly supplementing the wire antenna for shipboard installations. The wire antenna is used on many installations, often as an emergency antenna, as well as for special fan antennas which have broad band characteristics.

Antenna wire is usually a stranded, bare, phosphor or silicon-bronze wire. For transmitting, a 5/16-inch diameter wire is commonly used; and a 1/8-inch diameter wire is commonly used for receiving. The wire is continuous from the entrance insulator to the far end. Good installation practice requires that it be free from splices, kinks, sharp bends, deformed spots, and broken strands. The length depends on the frequency that is being transmitted, the space that is available, and other considerations.

In addition to the necessary wire, an antenna installation requires such items as supporting insulators, turnbuckles, clamps, shackles, safety links, staples, and pad eyes.

A *wire antenna* installation is illustrated in figure 5-30. The methods of installing antennas are included in Shipboard Antenna Details, NavShips 900121 (revised).

Whip Antennas

Whip antennas give a neater topside appearance and on carriers they are a practical necessity as the hazard to aircraft is reduced by use of the tilting types. Whip antennas have become increasingly important to shipboard installations due to the use of antenna tuners and couplers. There are also *special types of* whip antennas, such as the dual-frequency discage, and the top-loaded stub discone which provide broad band characteristics for use with multicouplers.

Because whip antennas are essentially self-supporting, they may be installed in many locations aboard ship either horizontally or vertically. They may be deck mounted or mounted on brackets on the stacks, superstructure, etc. If

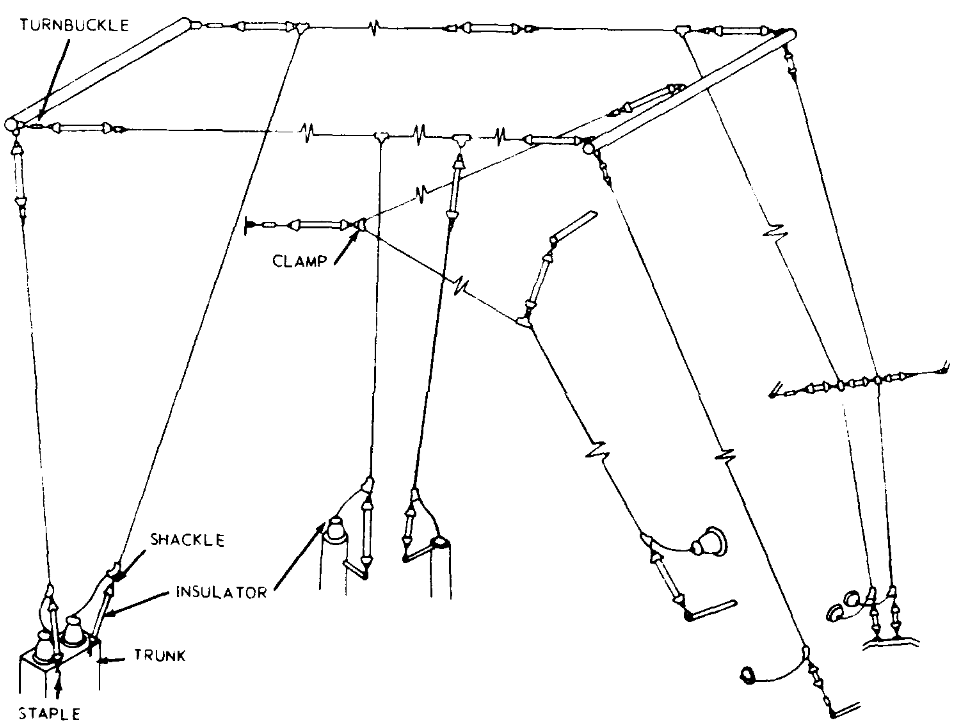


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Figure 5-30.—Wire antenna installations.

the stack is used, the outer casing will usually have to be reinforced to support the added weight and stress. When the whip antenna is installed on a stack, it is usually mounted near the top and approximately 24 inches away from the stack. In all installations of whip antennas, allowance is made for swaying of the whip. The whip is mounted in a clear space where it cannot strike other objects.

Whip antennas that are used for receiving only are mounted away from the transmitting antennas so that a minimum of energy from the transmitter will be picked up.

The preferred method of mounting whip antennas on shipboard is shown in figure 5-31.

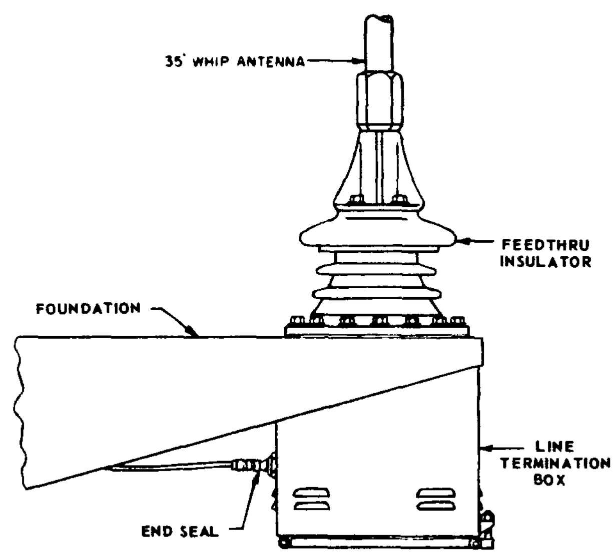
VHF and UHF Antennas

The physical size of antenna elements decreases as the frequency increases. Antennas that operate in the VHF (30-300 mc) and UHF (300-3000 mc) frequency ranges are relatively small in size. Because line-of-sight communication is used in the VHF-UHF ranges, high power is not necessary. Receiver signal strength then depends upon antenna height and the distance from the transmitter.

In these frequency ranges, it is important that both the transmitting and receiving antennas have the same polarization. The Navy employs vertical polarization in the VHF-UHF ranges.

Vertical conductors such as masts, rigging, and cables in the vicinity of UHF antennas will cause unwanted directivity. For this reason, these antennas are mounted as high and as much in the clear as possible.

Figure 5-32 shows two types of shipboard antennas operating in the VHF-UHF frequency range. Usually, either a vertical quarter-wave stub with a ground plane (part A) or a vertical half-wave dipole (part B) is used. The ground



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F ure 5-31.—Method of mounting a whip antenna.

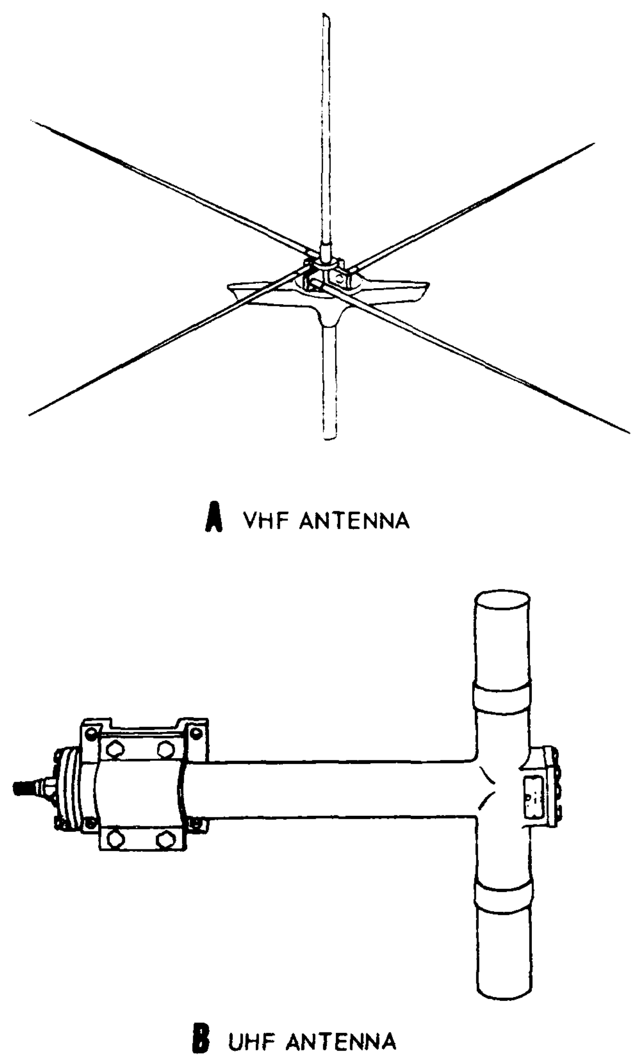

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Figure 5-32.—Types of VHF and UHF shipboard antennas.

plane prevents the metallic support mast from acting as a radiating portion of the antenna. It establishes the ground level at the base of the antenna.

Microwave Antennas

Parabolic-shaped reflectors are generally used to direct microwaves in the desired direction and in the required pattern.

Figure 5-33 illustrates that the energy from a radiating element placed at the focal point of a parabolic reflecting surface will be reflected into a narrow beam. Two types of parabolic reflectors used for microwave operation are shown in figures 5-34 and 5-35. (Other types—for example, the parabolic cylinder and the paraboloid—are used in aircraft; the paraboloid is also used aboard ship in fire control radars.) These reflectors are usually fabricated from solid metal or metal screening. In most instances these reflectors are placed on rotatable mounts.

The transmission lines used at microwave frequencies are coaxial lines or waveguides, using either a front- or a rear-feed system. In a front-feed system the waveguide or coaxial line approaches the reflector from the front and directs the spray of r-f energy into the reflector. In a rear-feed system the coaxial line or waveguide projects through the reflector from the rear, and an additional parasitic reflector is placed in front of the radiating element to direct the energy back toward the parabolic reflector.

RECEIVING-ANTENNA DISTRIBUTION SYSTEMS

Various types of shipboard receiver-antenna distribution systems are in use. Some systems are for small vessels and special applications

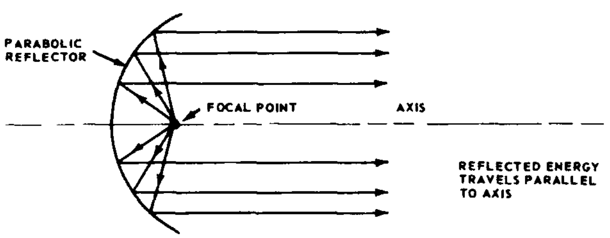

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Figure 5-33.—Principles of parabolic reflection.

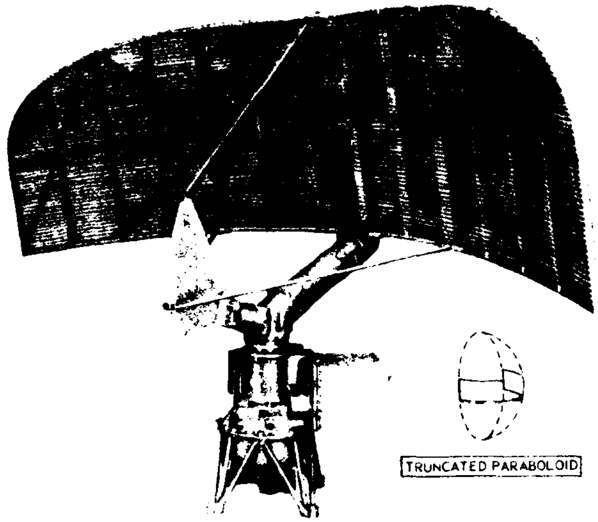

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Figure 5-34.—Antenna installation utilizing the truncated paraboloid.

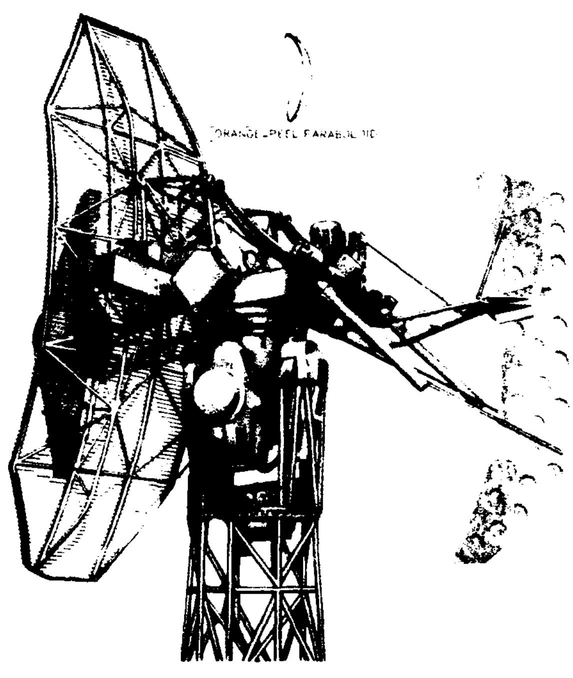

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Figure 5-35.—Antenna installation utilizing the orange-peel paraboloid.

only. Antenna transfer panels or more recently filter assemblies (multicouplers) have replaced the older systems utilizing terminal boxes.

These transfer panels (fig. 5-36) provide means for operating as many as four radio receivers simultaneously into one antenna. At the transfer panel, each antenna is connected to a row of four jacks. One jack is connected directly to the antenna; the other three jacks are connected in parallel through 600-ohm decoupling resistors. The receivers connected to the three decoupled jacks will operate at a reduced efficiency.

Operation of many receivers from a single antenna is possible utilizing the antenna filter assembly (fig. 5-37). These systems are discussed in more detail in chapter 8.

TRANSMITTING ANTENNAS AND TRANSMISSION LINES

In general, radio transmitting and receiving antennas are similar except that in the case of transmitting antennas much larger amounts of r-f power are handled. Because transmitting antennas present a hazard to personnel, the transmitting antenna installation is planned with the safety of the personnel in mind. For the proper safety precautions to be taken when work is done on antennas or transmission lines, see chapter 2 of this training course. See also United States Navy Safety Precautions, OpNav 34P1, and chapter 67 of Bureau of Ships Manual. For additional information, see General Installation Specifications For Shipboard Radio Transmitting Antenna Systems, RE 66A430.

In shipboard radio transmitting systems, both openwire and whip antennas are used. In older ships the transmission line for the antenna consists of a copper bus enclosed in an antenna trunk for use with high-power transmitters. Coaxial cable may also be used for the transmission line between the transmitter and its antenna, and has become the preferred method of connecting an antenna to its transmitter.

The term "trunkline" is applied today to those coaxial cables which interconnect internal antenna panels.

It is necessary to minimize the power losses in the transmission line if most of the power from the transmitter is to be radiated from the antenna. Matched impedances are maintained as closely as practicable in the antenna system to avoid high voltage-standing-wave ratios. In

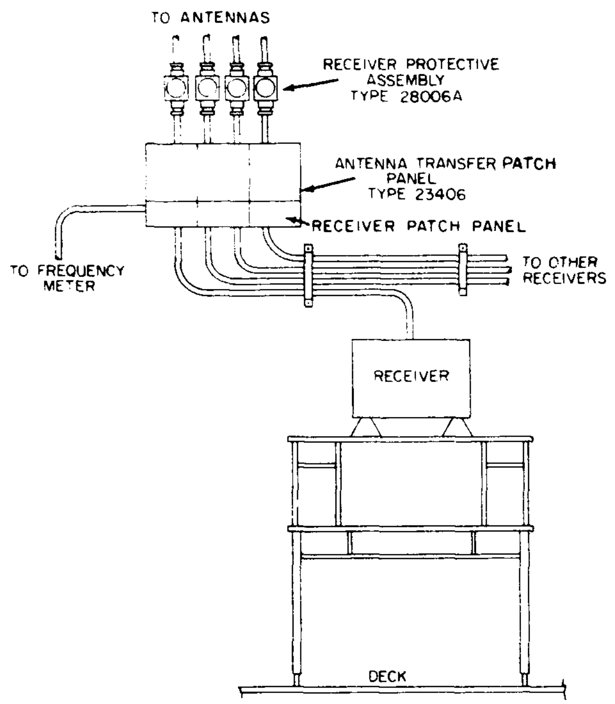

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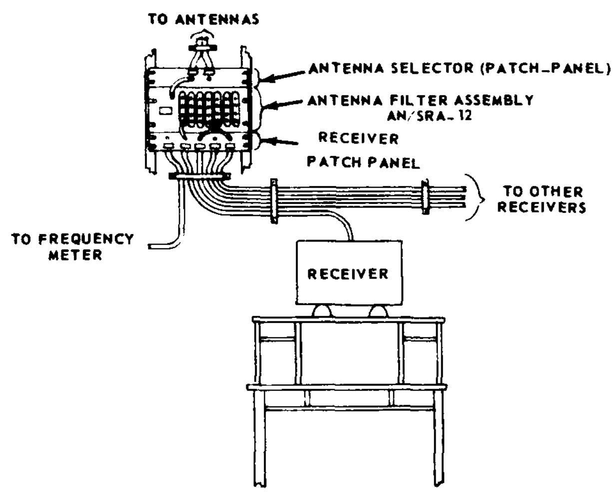
Figure 5-36.—Receiving antenna distribution system using transfer panel.



1.51.2
Figure 5-37.—Receiving antenna distribution system using filter assembly.

general, all r-f transmission lines should be as short as possible.

A transmitting wire antenna trunkline assembly that can still be found in older installations is illustrated in figure 5-38. The purpose of the trunk is to carry energy from the transmitter to the wire antenna with minimum loss, minimum interference, and maximum safety.

The disconnect switch has three positions: GROUND, CLOSED, and OPEN. The switch has a shield, or blanking-off plate, which is inserted into the trunk section of the switch between the switch mechanism and the bus leading to the transmitter. An interlock prevents the shield from being inserted into the slide except when the switch is in the GROUND position. This prevents closing the switch again before the shield has been removed.

The Transmitting Antenna Transfer Patch Panel (fig. 5-39) is manufactured in Shipyards and provides efficient use of transmitting antennas. It also provides protection to the associated transmitters. The antennas are permanently connected to the panel, either through HF multicouplers or directly, along with the transmitters. A patching facility provides combinations of antenna and transmitter connections. The connections are made in some panels at jacks which contain transmitter-enabling microswitches. If a coaxial connection is not fully completed at the patch panel, the transmitter concerned will not radiate because the microswitch has not operated. This prevents arcing at the coaxial plug and damage to the transmitter.

MULTICOUPLERS

Because of the increasing number of communications equipments required aboard naval vessels, it has bacome difficult to find suitable locations for the necessary additional antennas. One approach to the problem has been the use of multicouplers. These devices permit the simultaneous operation of a number of transmitters and/or receivers into a single antenna. Thus, the number of antennas can be reduced without sacrificing any of the required communications channels. This arrangement permits maximum use of the best available antenna locations and reduces the intercoupling between antennas.

Much research and development is being done on multicouplers, and various types have been designed to cover different frequency ranges and to operate with either receivers or transmitters or both. Filter-type multicouplers are described in detail in chapter 8 of this training course.

VHF-UHF Multicouplers

One type of VHF-UHF multicoupler (the CU-255/UR) is shown in figure 5-40. When six units are used (as shown), a system is provided for operating six transmitters (and/or receivers) into a single antenna. One coupler is required for each transmitter or receiver, or transmitter-receiver combination. The frequency range of this particular equipment is 230 to 390 mc.

These couplers can be tuned manually to any frequency in this range. When used with automatic tuning transmitter equipment they may be tuned automatically to any one of 10 preset channels in this band by dialing the desired channel locally on the transmitter or on a remote channel selector.

This coupler consists of two major components: the coupling cavity, or r-f section, and the automatic-drive mechanism.

The r-f section is essentially an impedance-matching device. It is capable of transforming antenna loads ranging from 50 to 125 ohms into 50 ohms at the r-f feedline terminal. This results in maximum power transfer to or from the antenna system.

Correct adjustment of the tuning controls is indicated by the meter on the front panel of the unit. This meter indicates the output from the reflectometer, which is a device for indicating the magnitude of the power reflected back from the coupling circuit. When the controls are adjusted so that the tuning indicator reads zero, the system impedances are properly matched and there is minimum reflected power in the system.

This multicoupler is designed to be mounted vertically on a bulkhead or other solid support on small ships. Space limitations, however, may dictate other arrangements. In some cases, the couplers may be mounted horizontally overhead. This position, however, is inconvenient from the point of view of tuning.

A typical TED-AN/URR-13/35 installation employing multicouplers (CU-332A/UR) is illustrated in figure 5-41. One coupler unit is required for each transmitter or receiver, or transmitter-receiver combination.

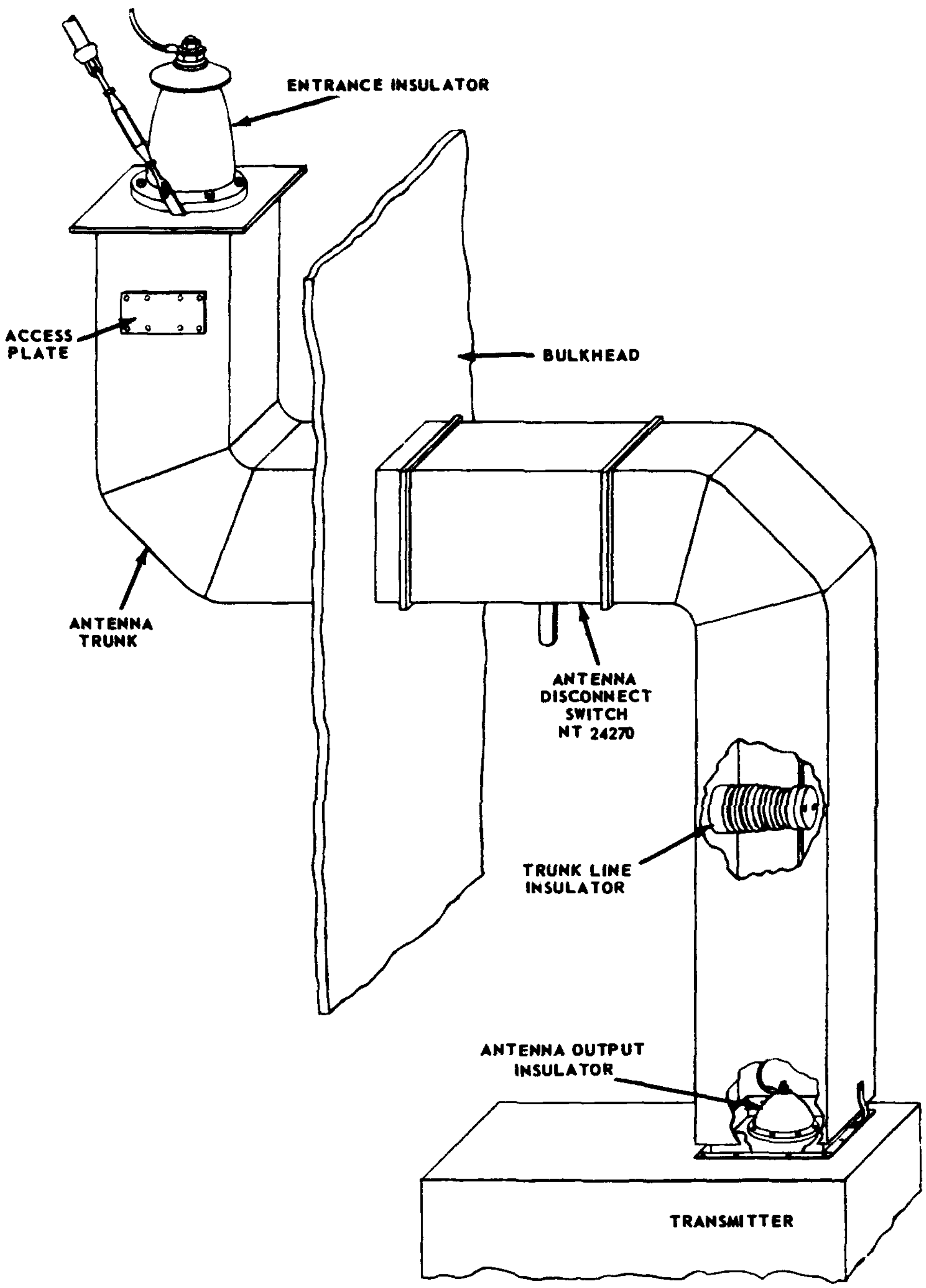


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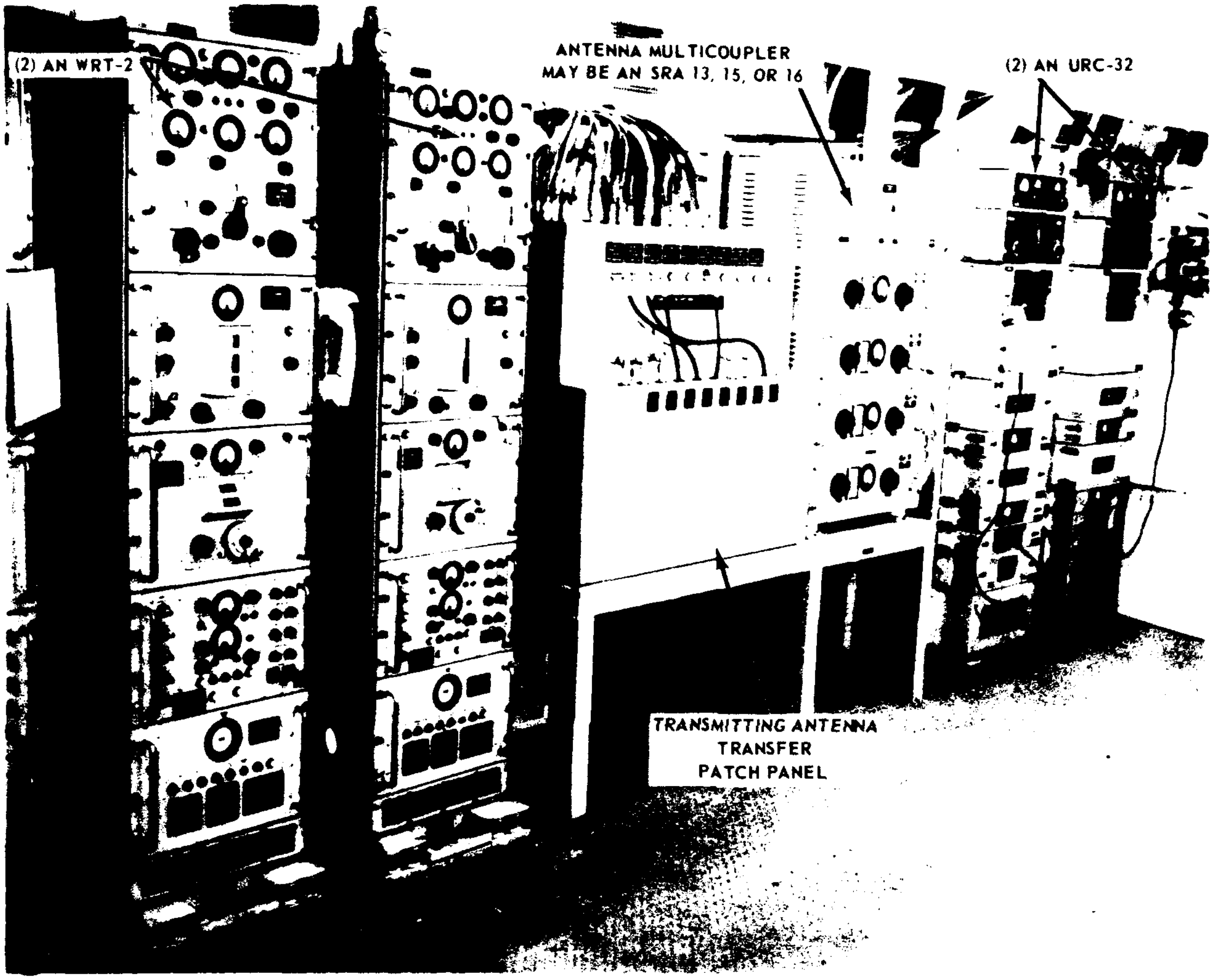
Figure 5-38.—Transmitting wire antenna trunkline assembly.

The CU-332A/UR multicoupler is identical to the CU-255/UR multicoupler previously described except for the drive mechanism. The CU-332A/UR provides for manual tuning only; whereas, the other has both automatic and manual tuning.

The CU-332A/UR coupler is used with manually tuned UHF equipment, such as the Model



70.27
Figure 5-39.—Transmitting antenna transfer patch panel and associated equipment.

TED transmitter and the AN/URR-13/35 receiver, or any other manually tuned equipment operating in the 230- to 390-mc frequency range.

HF Multicouplers

A system of h-f antenna couplers has been developed for simultaneously operating up to four transmitters into the same antenna in the frequency range of 2 to 26 mc. These antenna couplers are made up into four channel groups, each group operating in one of the following bands: 2-6 mc, 4-12 mc, 6-18 mc, and 9-26 mc. To obtain complete coverage from 2 to 26 mc, four coupler groups and four broad-band antennas are required.

The four types of h-f couplers are the AN/SRA-13, 14, 15, and 16. The AN/SRA-15 coupler (fig. 5-42) which is typical of this group of couplers, provides for the simultaneous operation of four 500 w. transmitting equipments into a single broad-band antenna.

It covers the frequency range from 6 to 18 mc and will operate into any antenna having a standing wave ratio (relative to 50 ohms) of 3 to 1 or better. The four transmitters connected

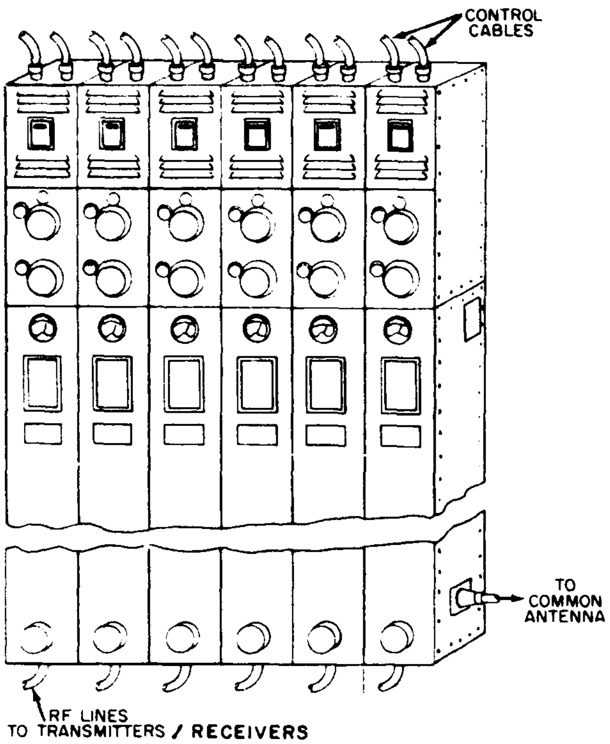


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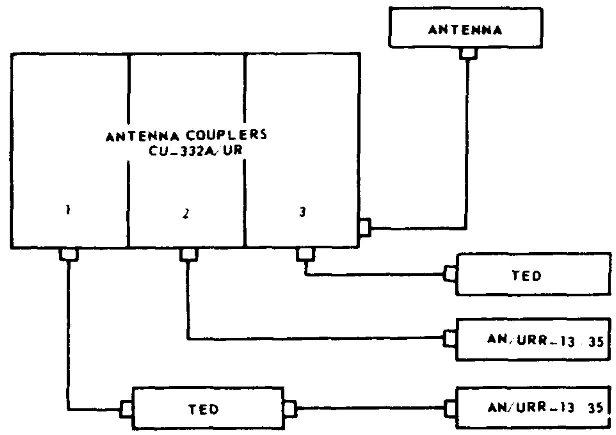
Figure 5-40.—VHF-UHF multicoupler (CU-255/UR).



70.27
Figure 5-41.—TED and AN/URR-13/35 installation employing a multicoupler.

to this coupler may be operated anywhere in the frequency range from 6 to 18 mc provided there is sufficient separation between the operating frequencies.

FILTERS

Modern electronic receiving equipments are being made with greater sensitivities, and this has increased the problem of radio interference generated by electromechanical devices such as motors, generators, relays, etc. Likewise, the interactions between the various equipments can cause major interference problems.

Good installation practices will reduce or perhaps eliminate radio interference, but a filter may be needed to reduce certain types of interference to a tolerable level.

The major sources of radio interference are summarized as follows:

1. ATMOSPHERIC NOISE—caused by lightning. The reduction of this noise is accomplished by the use of noise limiters and f-m.

2. PRECIPITATION STATIC—a problem chiefly in aircraft caused by static discharges and corona on snow, dust, rain, etc. It is identified by a frying sound. Special measures are needed for its reduction or elimination. On surface ships proper grounding of equipments and mast structures will generally reduce this type of disturbance.

3. BACKGROUND NOISE—due largely to shot effect (bombardment of the tube elements by irregularly spaced bunches of electrons), thermal noise (agitation of electrons in resistances because of heat), and microphonic noise (generally due to vibration of electron-tube elements).

4. COSMIC NOISE—the result of radiations from space. It is fast becoming a limiting factor in the design of more sensitive receivers.

5. MAN-MADE NOISE—may be generated by a variety of sources. These sources include rotating electrical machinery, ignition systems, relays, pulse-type equipment (for example, radars), interaction between equipments, diathermy, induction heating and welding equipment, hum pick-up at power or audio frequencies, and systems employing ionization of gas vapors.

Another type of interference that must be dealt with is that caused by operating several receivers from one antenna, as in MULTICOUPLER INSTALLATIONS. Various combinations of filters are used to feed the appropriate frequencies to the various receivers.

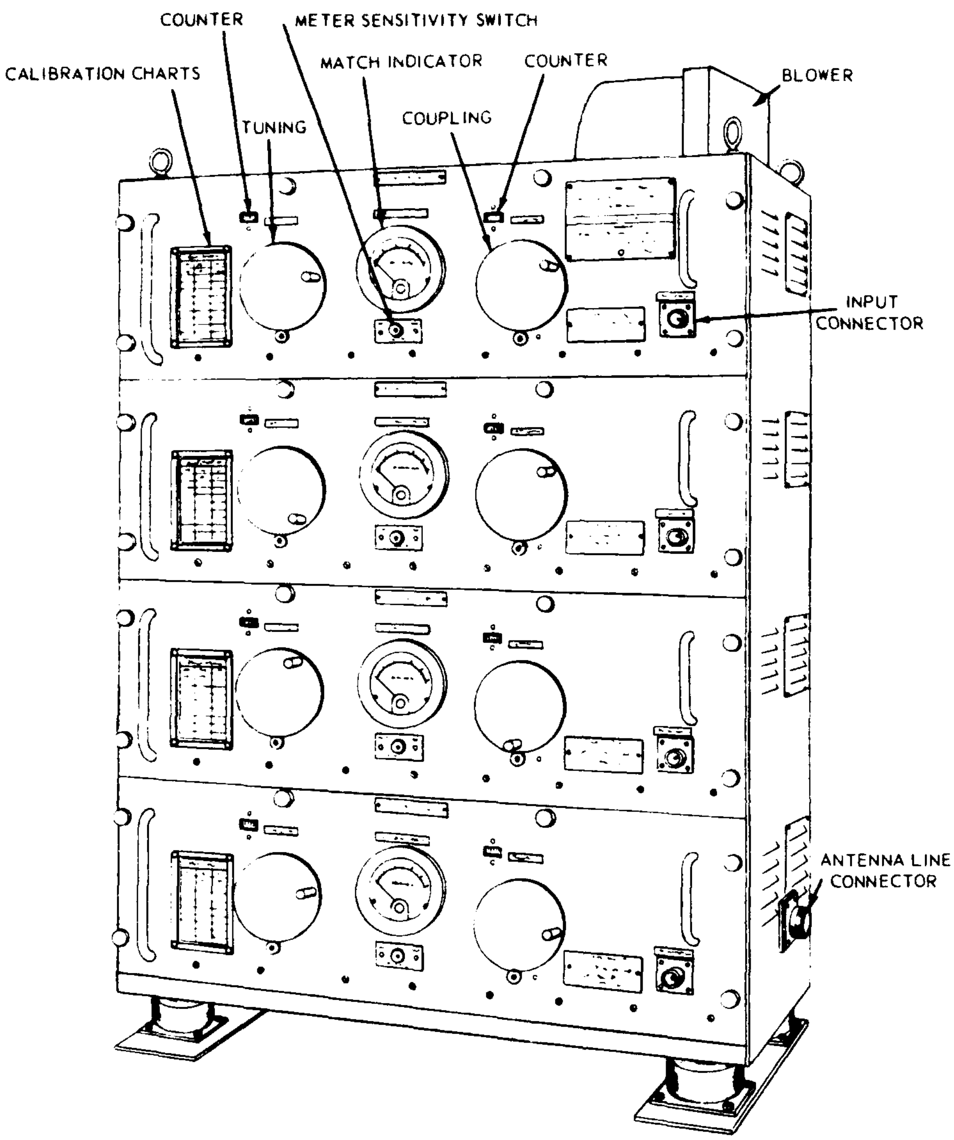


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Figure 5-42.—Antenna multicoupler AN/SRA-15.

Signal or noise interference may be transferred from one circuit to another by several means. They include:

1. CAPACITIVE or ELECTROSTATIC coupling in which one circuit is linked to another by means of a capacitance that is common to both. This is especially true at radio frequencies.
2. INDUCTIVE or ELECTROMAGNETIC coupling in which a conductor is present in the electromagnetic field set up by the noise interference. This type is the hardest to isolate.
3. DIRECT RADIATION, which involves essentially the same principle as radiation from a transmitting antenna to a receiving antenna.
4. CONDUCTION ALONG LINES, (conductive coupling) which is the tranfer of r-f energy along a conductor. It is this flow of signal or noise energy that is coupled by the methods

mentioned above and can be reduced or eliminated by the use of a filter or filter network at the noise source (fig. 5-43).

Types of Filters

ATTENUATION is the amount that the signal or noise voltage is reduced in a filter. It is measured in decibels (db). Decibels are discussed in Basic Electronics, NavPers 10087 (revised).

PASS BAND is the frequency range over which the filter passes signals with minimum attenuation (fig. 5-44).

STOP BAND is the frequency range over which the filter attenuates the applied signal.

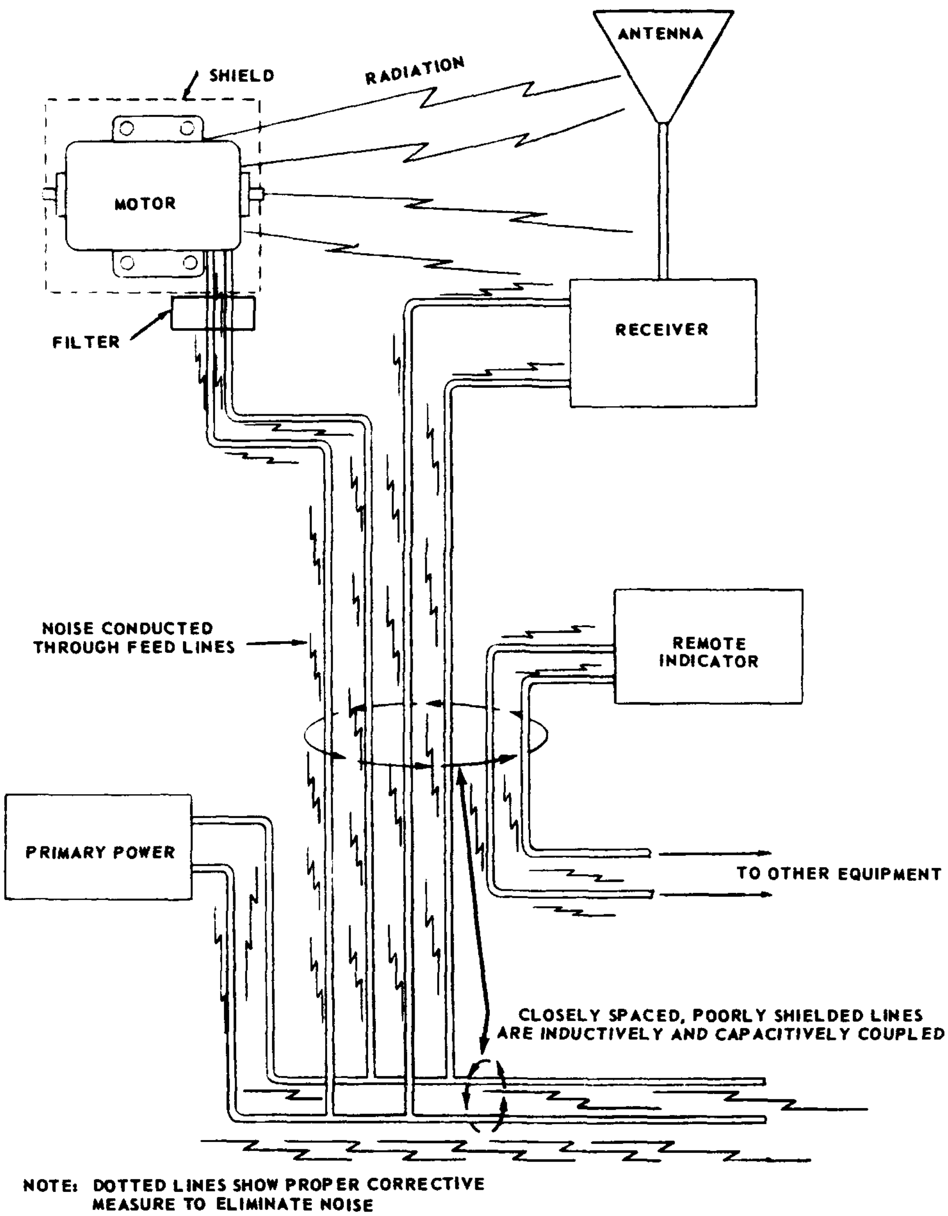

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Figure 5-43.—Radio noise coupling showing position of filter for noise elimination.

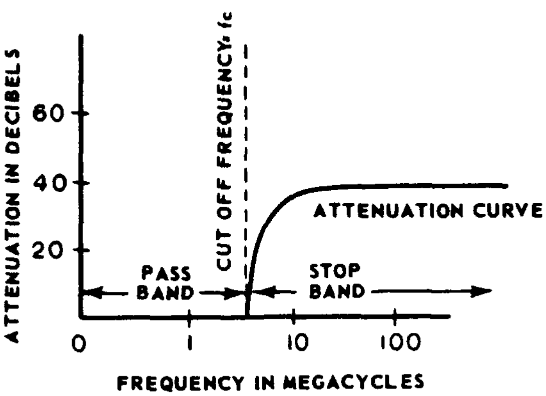

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Figure 5-44.—Illustration of the terms used in filters.

CUTOFF FREQUENCY is the frequency at which the filter changes from a pass-band to a stop-band filter or vice versa.

GROUND means the equipment frame, the chassis, shielding, filter housing, etc; it is an important part of the circuit.

LOW-PASS FILTER.—The low-pass filter passes all frequencies from zero frequency (fig. 5-45 A) (dc) up to the cutoff frequency (fc). All power lead filters fall in this class. For example, if it is desirable to pass 60-cycle power and to attenuate noise frequencies above (for example) 150 kc, a low-pass filter having a cutoff frequency of approximately 50 kc, may be used.

HIGH-PASS FILTER.—The high-pass filter attenuates all frequencies from zero frequency to the cutoff frequency and passes all frequencies above the cutoff frequency (fig. 5-45 B).

BAND-PASS FILTER.—This filter passes all frequencies within a specified range and attenuates all other frequencies (fig. 5-45C). Band-pass filters have special applications and are seldom used for noise elimination. One form of band-pass filter is the crystal filter used in communications receivers.

BAND ELIMINATION FILTER.—This filter attenuates a band of frequencies and passes all other frequencies (fig. 5-45D). It is most commonly used as a simple wave trap or absorption filter. Several wave traps are used in a television receiver.

Schematic diagrams of low-pass and high-pass filters are shown in figure 5-46.

Location and Installation of Filters

Filtering is done at the noise source whenever practicable. This eliminates or reduces interference caused by the noise source. It may be impracticable to filter at the source in the following cases:

1. When the source is an antenna that interferes with other antennas under operating conditions.
2. When the source feeds many multi-conductor cables and a filter would be required on every cable.
3. When the source is poorly shielded.

Three types of power-line filters are shown in figure 5-47. Filters may be mounted on bulkheads or on equipments.

The method of mounting a filter so that a bulkhead, chassis, or equipment case acts as an isolating shield between the input and output of the filter is referred to as bulkhead mounting (fig. 5-48). Very often, filters that are to be used in a component piece of equipment are designed for this type of mounting. This same principle may be applied to filters enclosed in a box mounted on the side of the equipment. It does not lend itself to watertight installations because the space through which the leads pass into the equipment cannot be effectively sealed.

Filters mounted on machines or other noise sources are illustrated in figure 5-49.

A good r-f connection is exceedingly important in filter installations regardless of whether it is a joint, a grounding surface, or a shield contact. Clean continuous r-f surfaces must be maintained throughout the installation. This means that all painted surfaces, at the point where electrical connections are made, must be cleaned to the bare metal.

Low-pass filters are used on many radio receivers—for example, the AN/SRR 11, 12, 13 and the AN/URR-35 (fig. 5-50).

The schematic diagram of this filter is shown in figure 5-51. The filter allows the necessary connections into and out of the rear of the receiver, but eliminates unwanted signals from passing through the lines. There are three main circuits through the filter: the antenna lead the a-c power lead, and the audio output lead.

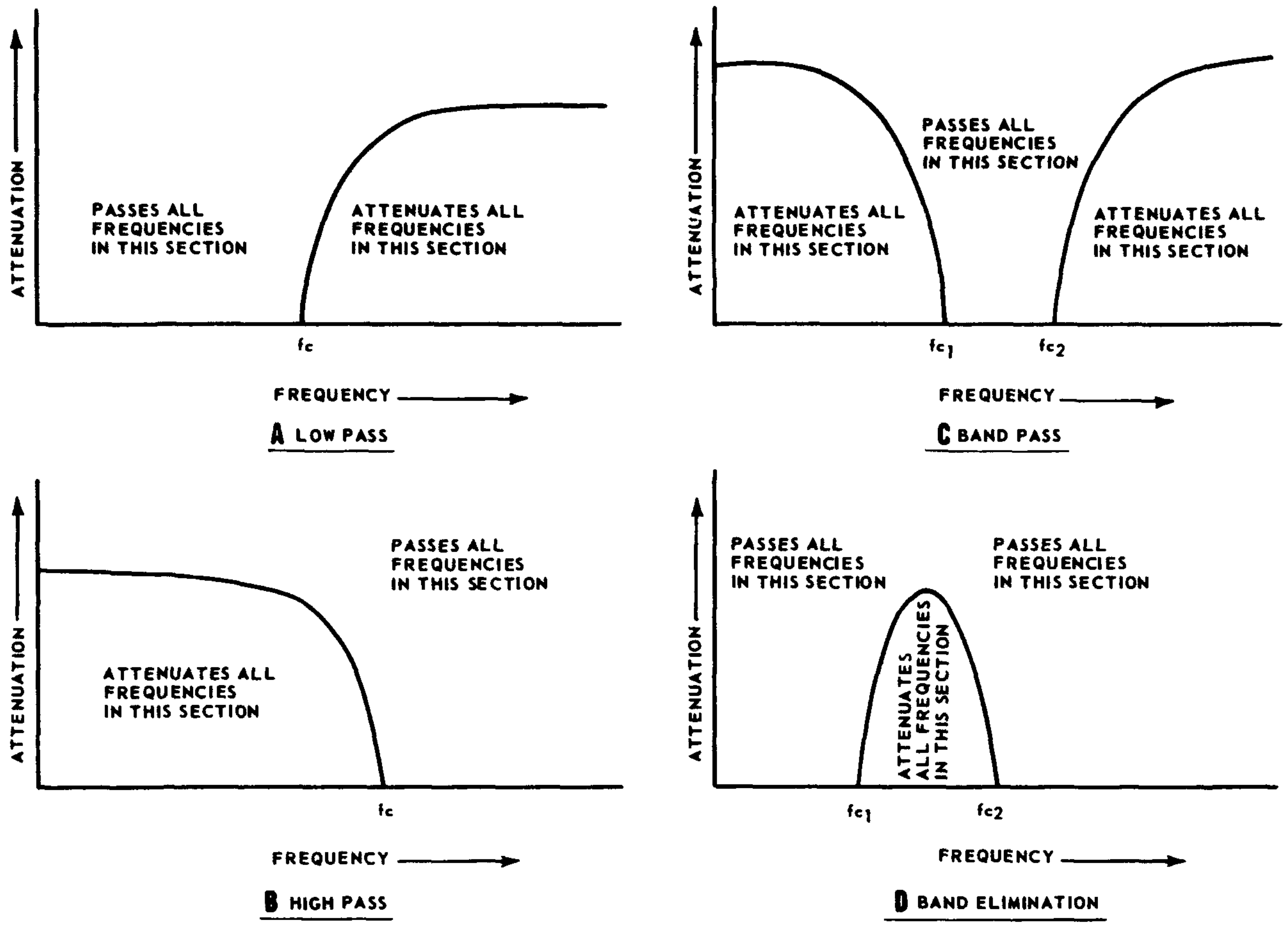

Figure 5-45.—Filter response curves.

R-f signals from an antenna are brought through a coaxial lead and connected to the antenna jack. They pass through the low-pass filter to the r-f amplifier unit.

Power for the receiver is connected to the power jack. The two-section, r-f filter eliminates any r-f energy that may tend to come in through the power lines. After passing through the filter, the power is fed to the receiver through terminals 70 and 71.

The audio signal from the receiver output transformer is connected through terminals 68 and 69 to the low-pass filter. The audio signals then pass through the two-section filter to the audio output (to speakers, etc). The filter allows the audio signals to pass through, but prevents any feeding back of r-f signals through the audio lines from outside the receiver.

Chapter 21 of EIPM, NavShips 900,171, contains additional information concerning filters.

POWER SYSTEM FOR ELECTRONIC EQUIPMENT

The power distribution system connects the generators of electric power to the equipments that use it. Built into the system are devices that protect the generators, the equipments that use the power, and the system itself from certain types of damage.

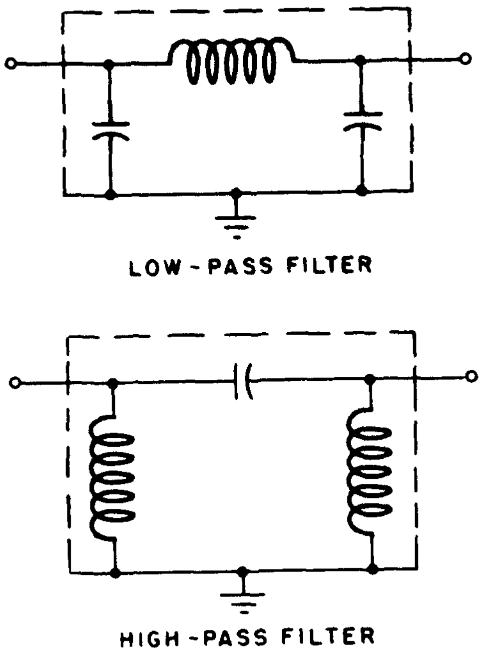

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Figure 5-46.—Low-pass and high-pass filters.

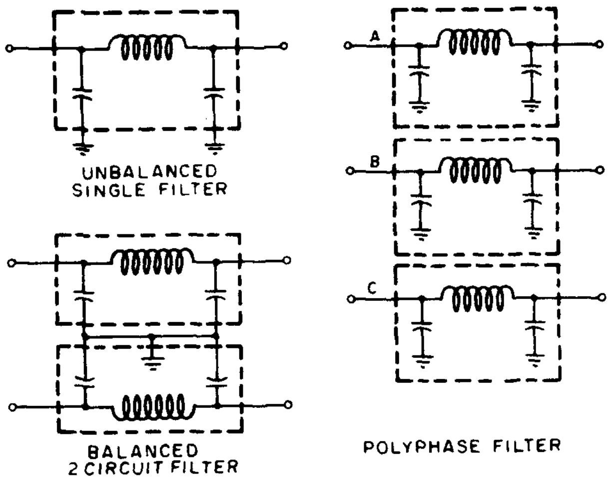

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Figure 5-47.—Types of power line filters.

A comprehensive distribution system includes the following:

1. SHIP'S SERVICE DISTRIBUTION SYSTEM includes the ship's service generators and the ship's service distribution system. It is the normal source of electric power.

2. EMERGENCY DISTRIBUTION SYSTEM includes at least one emergency generator and the emergency distribution system. An emergency system is installed on most ships to supply a limited amount of power for the operation of vital equipment when the ship's service system is incapacitated.

3. CASUALTY POWER DISTRIBUTION SYSTEM is installed on many ships to make temporary electrical connections if both the ship's service and the emergency distribution systems are damaged.

At least two independent sources of power are provided for selected vital loads (for example, steering, I. C. and F. C. switchboards, and ordnance equipment). This is done by means of a normal and an alternate ship's service feeder; or a normal ship's service feeder and an emergency feeder; or, in some cases, both normal and alternate ship's service feeders plus an emergency feeder.

Normal and alternate feeders run from different ship's service switchboards and are spaced as far apart as feasible to minimize the possibility that both will be damaged by a single hit.

Motor-Generator Sets

Motor-generator sets are used to change an available type of power to a desired type of power. The change may be from d-c to a-c, a-c to d-c, from one frequency to another, one voltage to another, or a combination of these.

Each motor-generator set consists of a driving motor and one, or sometimes two, generators. A coupling is provided to connect the motor and the generator mechanically together. In most motor-generator sets the stationary components of all the machines are rigidly coupled together on a mounting bed to maintain proper alignment (fig. 5-52).

In electronic applications, the motor-generator sets (when used) are usually designed to supply power to one particular equipment.

The Amplidyne

The amplidyne is a specially constructed d-c generator having a large ratio between

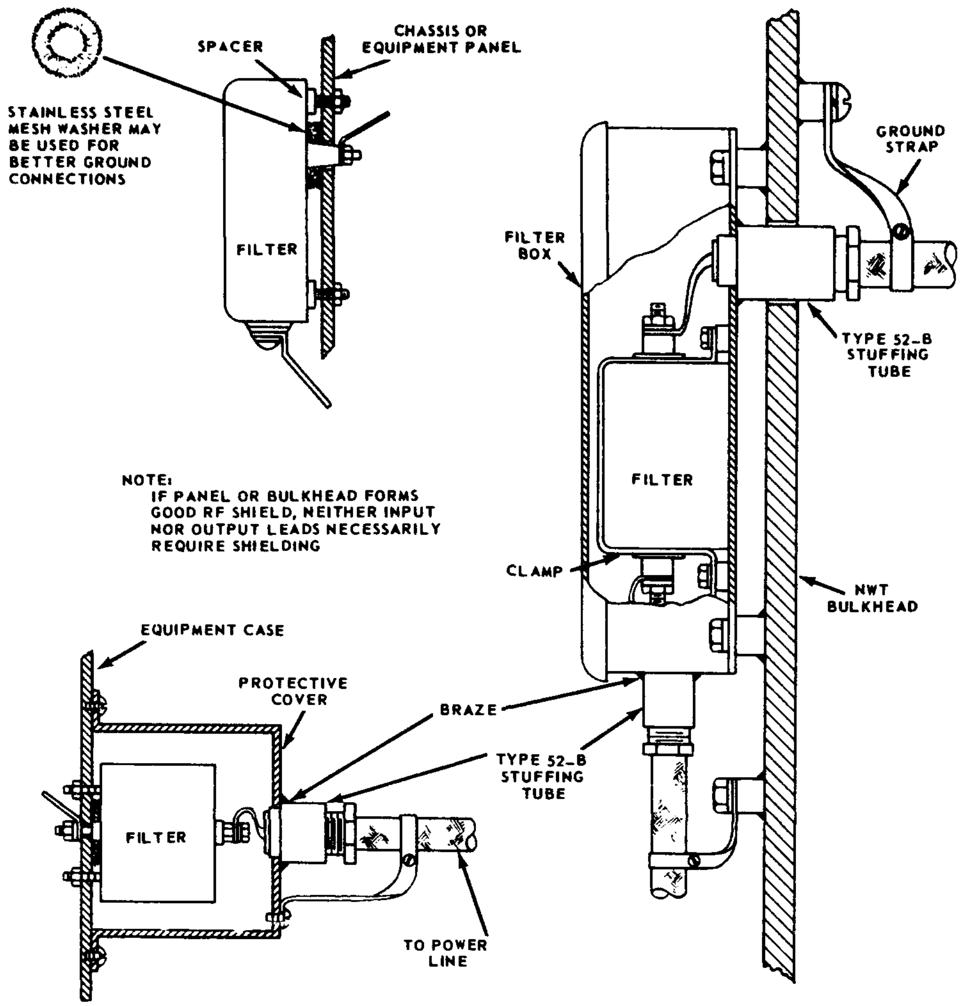

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Figure 5-48.—Installations using bulkhead mountings.

field excitation (control power) and output power. Special windings are utilized in such a way that any change in control field strength causes a corresponding change (greatly amplified) in the armature output. Amplidyne motor-generators are used extensively in servo-systems. A remote control signal is fed to the amplidyne control field and is amplified in the armature output. The output furnishes power to a d-c motor that may make a gun or antenna move in the direction and speed required by the remote signal. The amplidyne group used with the AN/SPS-8 radar is shown in figure 5-53.

Each of the five amplidyne motor generators weighs about 160 pounds. They are supplied with 450-volt, three-phase current. The top generator produces the 425-volt, d-c (B+) needed by the equipment; the others provide 250-volt, d-c power for the roll, pitch, scan, and train motors.

Amplidynes are also used as voltage regulators and exciters for a-c generators, and in turboelectric propulsion systems.

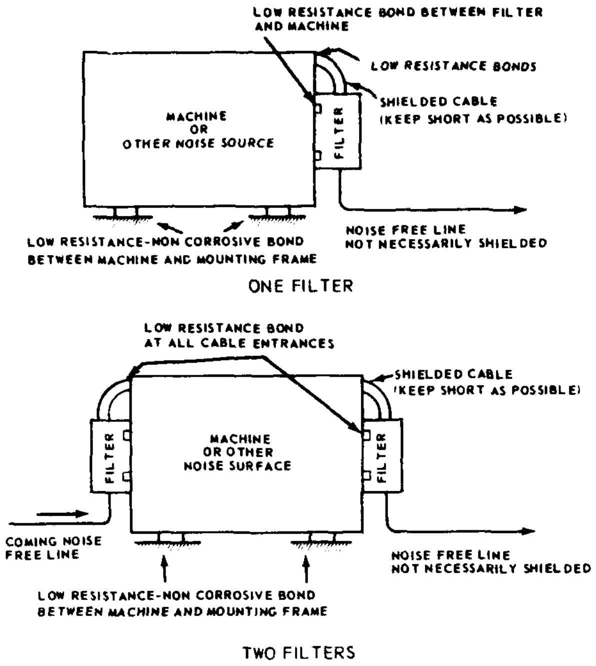

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Figure 5-49.—Low-pass filter on a machine or other noise sources.

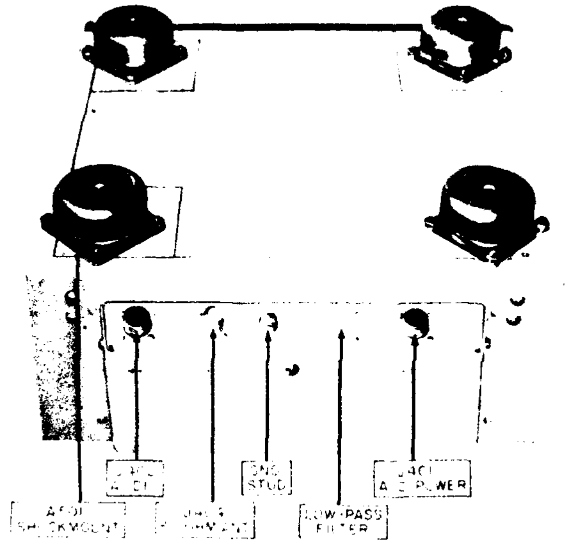

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Figure 5-50.—Low-pass filter used with the AN/URR-35 radio receiver.

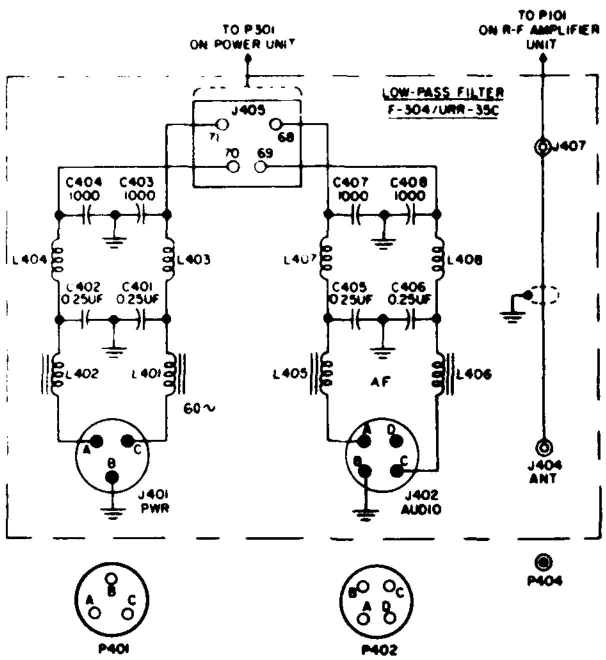

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Figure 5-51.—Schematic diagram of the low-pass filter used with the AN/URR-35 radio receiver.

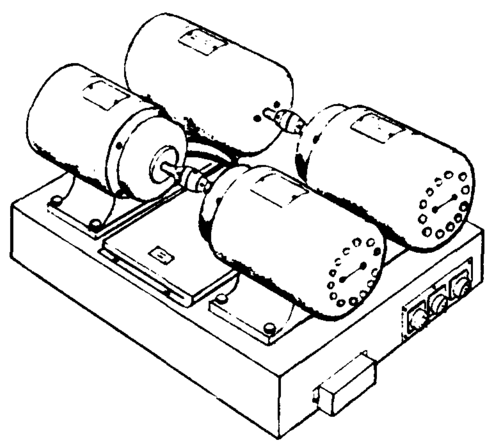

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Figure 5-52.—Motor-generator sets used for electronics equipment.

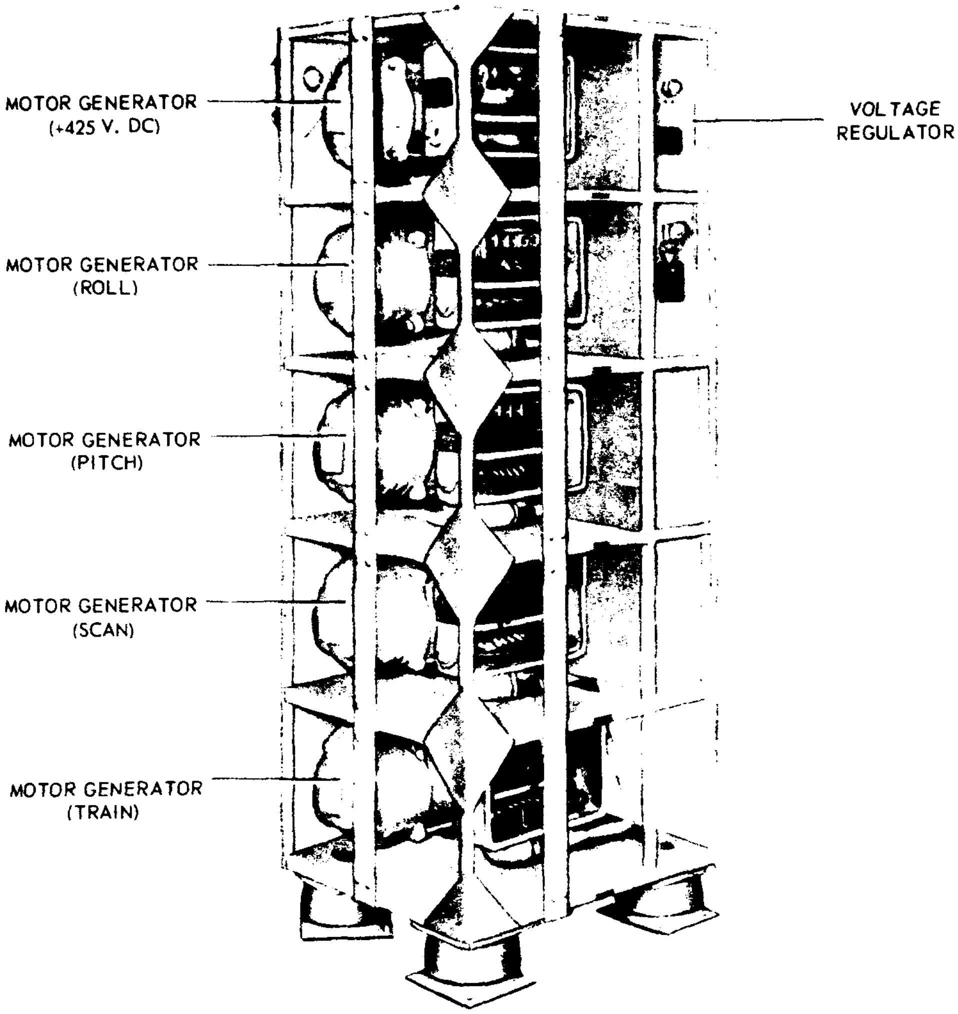

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Figure 5-53.—Motor-generator (amplidyne) group used with the AN/SPS-8 radar.

CHAPTER 6

USE OF TEST EQUIPMENT

The purpose of this chapter and the next is to better acquaint the technician with the practical use of test equipment. A cabinet or room full of test equipment is of little value if the technicians are not familiar with its use. Also, outdated or specialized equipment for testing or servicing electronic equipment that is no longer aboard ship is of no value and takes up valuable space.

In the POMSEE books the necessary instruments for testing the electronic equipments are listed near the front, and the technician will do well to become familiar with these instruments.

The next most important thing, after learning how to use a test instrument, is to learn how to take the proper care of the instrument. Practically no test instrument will stand up under abuse. A damaged test instrument that reads incorrectly is, in many instances, worse than having no instrument at all. A large percentage of test equipment failures can be avoided by careful handling, proper use of the equipments, and proper stowage at sea.

REPRESENTATIVE EQUIPMENT

Some idea of the extent of the test equipment needed aboard ship may be gained from the following list of equipments used for testing electronic gear. The list is not complete; however, it is representative. It is compiled from the available maintenance manuals.

Audio Oscillator: The Signal Generator TS-382C/U series.

Echo Box: Echo Box TS-275/UP.

Frequency Meters: The LM-21 (heterodyne type), FR-4/U, AN/USM-29, and AN/URM-82 series. About 18 different frequency meters (including both the absorption and the heterodyne types) are included in Electronic Test Equipment Application Guide, NavShips 91727. Newer meters, such as the AN/USM-26, and/or CAQI-524D (Counter type), are rapidly replacing the older heterodyne frequency measuring meters.

Insulation Tester: The Insulation Test Set AN/PSM-2 and Navy Models OCW and 60089 Insulation Resistance Testers.

Microammeter: D-c Microammeter Navy Model 60107.

Multimeter (Electronic): The ME-25A/U series.

Electronic Voltmeters: The ME-6A/U series.

Multimeter (Nonelectronic): The AN/PSM-4 and TS-352/U series.

Oscilloscope: The OS-8/U series; AN/USM-24, 32, and 38 series; and TS-34A/AP series.

Synchroscope: There seems to be no clear line of distinction between synchroscopes and oscilloscopes. Actually, a synchroscope is a special type of oscilloscope. Several have already been listed under oscilloscopes—for example, the AN/USM-24 and 32, and TS-34A/AP series.

Range Calibrator: The TS-573/UP series. This equipment, part of Test Set AN/MPM-23, supersedes Range Calibrators TS-102/AP and TS-358/UP, as well as the range calibrator functions of Oscilloscopes OS-7/U and 60ACZ-1.

Power Meter: The TS-230B/AP series. About 14 power-measuring equipments are listed in NavShips 91727. They cover various frequency ranges and have various degrees of accuracy.

Signal Generator: The AN/URM-25B series. Over 30 signal generators are listed in NavShips 91727.

Wattmeter, R-F: AN/URM-43

Tube Tester: TV-7/U series. This equipment is a portable tube tester designed to test and measure mutual conductance values of electron tubes used in receivers and the smaller transmitters.

Transistor Tester: TS-1100/U. This equipment is a portable test set which operates on dry cells with a life expectancy of 1000 hours. The tester (using Technical Manual 93277)

measures the amplification, or BETA, of a transistor without the need for removing the transistor from the circuit. In addition it will test for collector leakage current, with the transistor out of the circuit, and also for shorts.

CAPACITANCE-INDUCTANCE-RESISTANCE ANALYZER: Bridge ZM-11/U is a portable analyzer used in measuring and checking the characteristics of capacitors, resistors, inductors, and transformers to determine their value and condition. Capacitors are checked for leakage resistance, and inductors and transformers are checked for inductance.

COMBINATION TEST SETS: This type of test equipment permits more than a single characteristic to be checked, usually without switching. The following equipments are representative examples.

Analyzer TS-1074/TPM is a portable unit used in measuring or checking the frequency, wavelength, and power of radio transmitters, signal generators, and best-frequency oscillators. It will also measure the average power of CW, MCW, or pulsed radar sets and provide a video output signal for testing oscilloscopes.

Frequency-Power Meter TS-230B/AP is a portable radar test set used in measuring frequency and power of unmodulated and pulsed signals. It permits the detection of small percentages of rf power so that wave forms of pulsed signals can be displayed on an oscilloscope.

Test Set TS-146/UP is an F-M field unit used in measuring the power output and frequency of radar transmitters, as well as the sensitivity of radar receivers. In conjunction with an oscilloscope, this equipment is used in tuning radar receivers and TR boxes, measuring transmitter spectrum width and receiver bandwidth, determining TR box recovery time, checking magnetron pulsing and afc circuits, and tuning radar local oscillators.

Radar Test Set AN/UPM-99 was designed for maintaining and testing the Mark X and SIF type IFF equipment. The test set is comprised of a precision oscilloscope, trigger and suppressor pulse generators, Mark X and SIF code simulators, a pulsed RF signal generator and attenuator, a wavemeter, a demodulator, a pulse counter, and a calibrated video pulse generator. It operates through a range of RF inputs from 925 to 1225 mc. The following signal outputs are provided by the test set: triggers (zero time and delayed), suppressor pulses, Mark X and SIF interrogations and replies, internally or externally modulated RF pulses, and calibrated video pulses.

Radar Test Set AN/MPM-23 is a group of radar testing instruments required for maintenance at an advanced base. The test set is comprised of Power Supply PP-674/TPS-ID, Pulse Generator Set AN/UPM-15, Bridge Summation AN/URM-23, Signal Generators AN/URM-64, TS-452/U, and TS-497/URR, Electronic Multimeter ME-6/U, Motor Generator PU-20/C, Variable Power Transformer TF-171/USM, Fluxmeter TS-15/AP, Dummy Load TS-234/UP, Dummy Antenna TS-235/UP, Crystal Rectifier Test Set TS-268/U, Frequency Meter TS-328/U, and Range Calibrator TS-573/UP.

TYPES OF MEASUREMENTS

CURRENT, VOLTAGE, AND RESISTANCE MEASUREMENTS

The instruments and methods of making current, voltage, resistance, and power measurements in power and lighting circuits are included in Basic Electricity, NavPers 10086 (revised). It should be noted that the ETs will, in general, use multimeters in their work rather than separate instruments for measuring current, voltage, and resistance. For example, the AN/PSM-4 multimeter (nonelectronic) measures from 0 to 1000 volts a-c in 9 ranges, 0 to 4000 volts d-c in 10 ranges, 0 to 100 megohms in 5 ranges, and 0 to 10 amperes in 8 ranges. The ME-25/U multimeter (electronic) measures from 0 to 1000 volts a-c or d-c in 7 ranges, 0 to 1000 milliamperes in 6 ranges, and 0 to 1000 megohms in 6 ranges.

CAPACITANCE, INDUCTANCE, AND IMPEDANCE MEASUREMENTS

Combination capacitance, inductance, and resistance (impedance) measuring instruments commonly make use of some type of bridge arrangement employing standard units of capacitance, inductance, and resistance and some means (for example, a meter) of determining bridge balance. If C, L, and R are determined, X_C AND X_L, and Z may be computed for a chosen frequency. An elementary bridge circuit is treated in Basic Electronics, NavPers 10087 (revised).

The Capacitance-Inductance-Resistance Bridge, Type ZM-11/U can be used for measuring other quantities in addition to C, L, and R. It measures the turn ratios of transformers, the dissipation factor of inductors and capacitors, the storage factor (Q) of inductors at 1000 cps and insulation resistance of capacitors and other parts, as well as leakage in electrolytic capacitors when direct current is used. A brief description of the basic circuitry of the ZM-11/U (fig. 6-1) and the methods of making these measurements follows.

Note: Impedance measurements are included in all the following measurements except pure resistance.

Resistance Measurements

When the FUNCTION switch (upper left of figure 6-1) of the ZM-11/U is in the RESISTANCE (R) position, the circuit shown in simplified form in figure 6-2 is selected by the switch.

The four arms of the bridge are shown in the schematic diagram. Arm A contains the multiplier rheostat and a fixed resistor. When the multiplier rheostat is in position 1, arm A has a resistance of 1000 ohms; as it is moved to position 11, the resistance of arm A increases to 11,000 ohms. Arm B contains the range switch and the range resistors. Arm R_s contains one of the standard resistors; the correct standard resistor is connected into this arm by the range switch. The resistor of unknown resistance is connected in arm R_x.

The balance indicator is an electron-tube tuning indicator. The maximum possible opening of the pattern indicates balance. Balance is approached by proper positioning of the range switch, which connects the correct resistor in

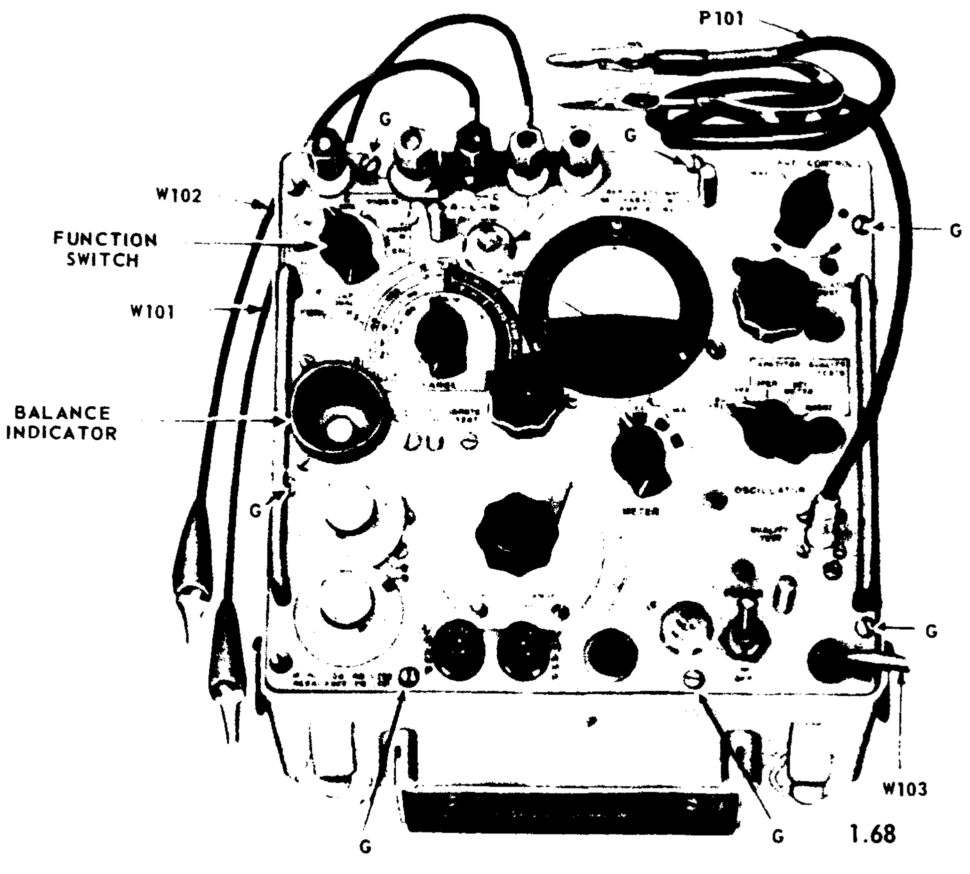

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Figure 6-1.—ZM-11/U bridge.

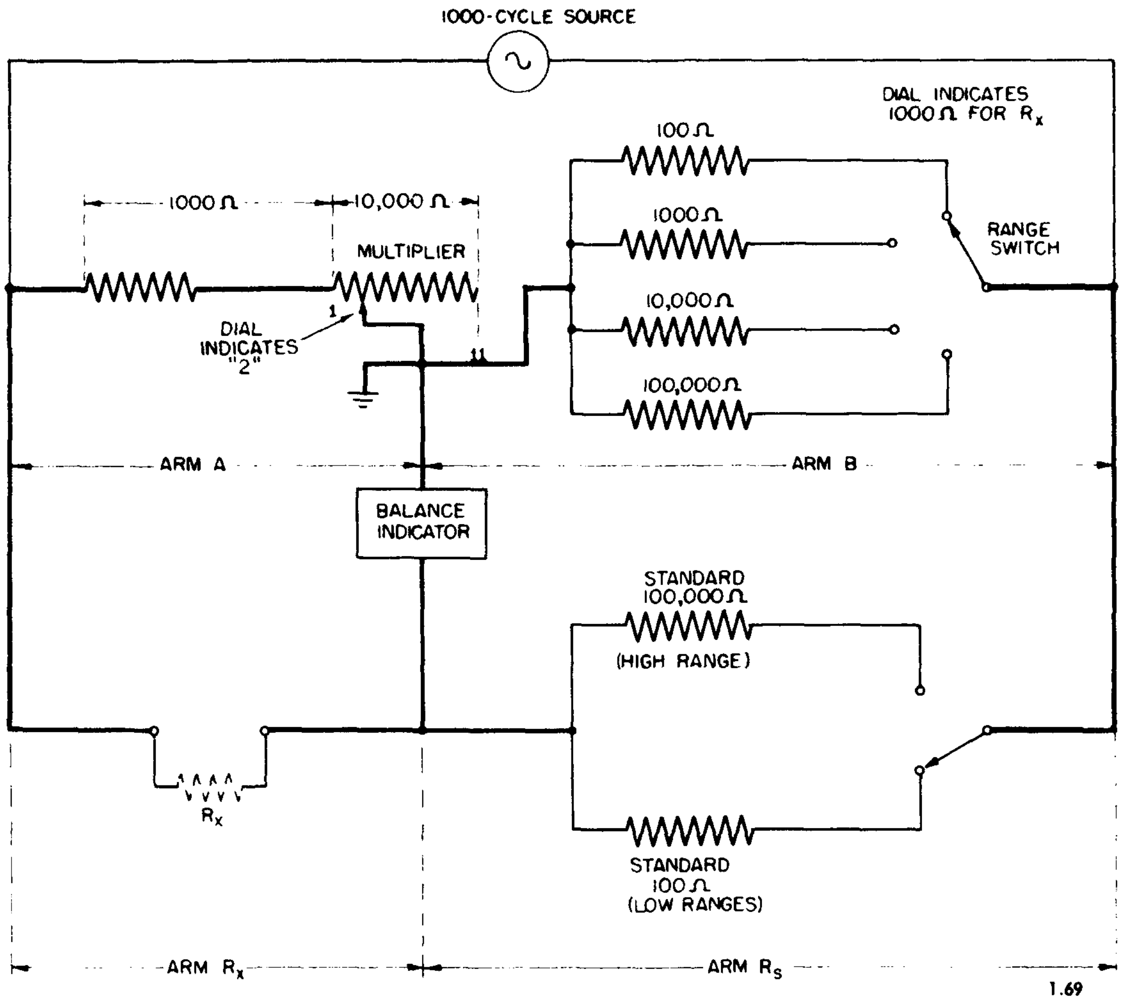

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Figure 6-2.—Resistance bridge.

arm B and the correct standard resistor in arm R_S; balance is then completed by adjustment of the multiplier rheostat.

As the multiplier is moved through the point of balance, the balance indicator pattern increases to a maximum (point of balance) and then decreases again. This action results from the fact that the voltage across the indicator decreases to zero as the exact point of balance is reached and then it increases again as the multiplier is moved beyond the point of balance. The same reasoning may also be applied to capacitance and inductance measurements.

As a practical example of resistance measurement, assume that at balance the multiplier is at position 2 (the resistance of arm A is 2000 ohms), the range switch is in the position shown (100 ohms in arm B), and that 100 ohms standard is used in arm R_S. These positions are indicated in the figure.

Under conditions of balance,

$$\frac{A}{B} = \frac{R_X}{R_S},$$

where A is the resistance of arm A, B is the resistance of arm B, R_X is the resistance of

the unknown resistance, and R_s is the resistance of the standard resistor.

Substituting the values previously given,

$$\frac{2000}{100} = \frac{R_x}{100}$$

$$R_x = \frac{2000 \times 100}{100} = 2000 \text{ ohms.}$$

On the instrument itself, the range switch (which has a calibrated dial) will indicate 1000 ohms, and the multiplier dial (which is also calibrated in units and tenths—from 1 to 11) will indicate 2; the reading will therefore be 2000 ohms. That is, 1000 ohms on the range switch multiplied by 2 on the multiplier dial is equal to 2000 ohms.

The same procedure is followed in making capacitance and inductance measurements. In each case the range switch indication is multiplied by the multiplier dial indication to determine the value of the unknown capacitor or inductor.

Capacitance Measurements

When the FUNCTION switch of the ZM-11/U is in the CAPACITANCE (C) position, the circuit shown in simplified form in figure 6-3 is selected by the switch.

Arm A contains the stray capacitor compensator. This compensator is used only on the lower capacitance ranges, and is automatically positioned by the range switch. Its function is to compensate for stray capacitance associated with the connecting leads in arm C_x. The error that would otherwise be introduced is significant only when small capacitances are measured, and the lead capacitance is of the same order of magnitude as that of the capacitor itself. Arm A also contains the multiplier resistor and a 1000-ohm fixed resistor. When the multiplier is in position 1, the resistance of arm A is 1000 ohms. The resistance increases to 11,000 ohms when the multiplier is moved to position 11.

Arm B contains the range switch and the range resistors, and arm C_x contains the capacitor of unknown capacitance.

Arm C_s contains a standard capacitor (one of two), which is selected automatically by the range switch, and the necessary dissipation control rheostat. The dissipation (D) dial associated with the rheostat indicates the dissipation factor (power factor) of the capacitor under test. Each of the two standard capacitors has its associated dissipation control rheostat. When the 1000 $\mu\mu f$ standard is used, the 10,000-ohm rheostat is in the circuit. As the resistance of the rheostat is increased through the 10,000-ohm range, the D dial indicates a dissipation factor of from 0 to 0.06. When the 100 μf standard is used, the 100-ohm rheostat is in the circuit. As the resistance of the rheostat is increased through the 100-ohm range, the D dial again indicates a dissipation reading of from 0 to 0.06, but in this case, the reading must be multiplied by 10 to obtain the dissipation factor (0 to 0.6).

As a practical example, assume that at balance the controls are in the positions shown. Arm A has a resistance of 2000 ohms, arm B has a resistance of 100 ohms, arm C_s utilizes the 1000-$\mu\mu f$ standard with a certain amount of resistance in series with it, and arm C_x contains the capacitor of unknown capacitance with its effective series resistance. Because the purpose of the dissipation rheostat is to make the power factor of arm C_s equal to the power factor of arm C_x to perfect the bridge balance, the resistance of the rheostat need not be considered in the following bridge equation:

Under conditions of balance,

$$\frac{A}{B} = \frac{C_x}{C_s}.$$

Performing the substitutions,

$$\frac{2000}{100} = \frac{C_x}{1000\ \mu\mu f}$$

$$C_x = \frac{2000 \times 1000}{100} = 20{,}000\ \mu\mu f = 0.02\ \mu f = 2 \times 10^{-8} \text{ fds}$$

Under conditions of balance, the power factor ($\cos\theta = D$) of arm C_s is equal to the power factor of arm C_x. The calculations for the reactance and resistance of arms C_s and C_x for this example are

$$X_{cx} = \frac{1}{\pi\ fC_x} = \frac{1}{6.28 \times 10^3 \times 2 \times 10^{-8}} = 7950 \text{ ohms}$$

$$X_{cs} = \frac{1}{\pi\ fC_s} = \frac{10^{12}}{6.28 \times 10^3 \times 10^{-9}} = 159{,}000 \text{ ohms}$$

$$P_x = X_{c_x} \cos\theta = 7950 \times 0.03 = 238.5 \text{ ohms}$$

$$P_s = X_{c_s} \cos\theta = 159{,}000 \times 0.03 = 4770 \text{ ohms.}$$

Where the calibrated dissipation dial indicates a value of 0.03.

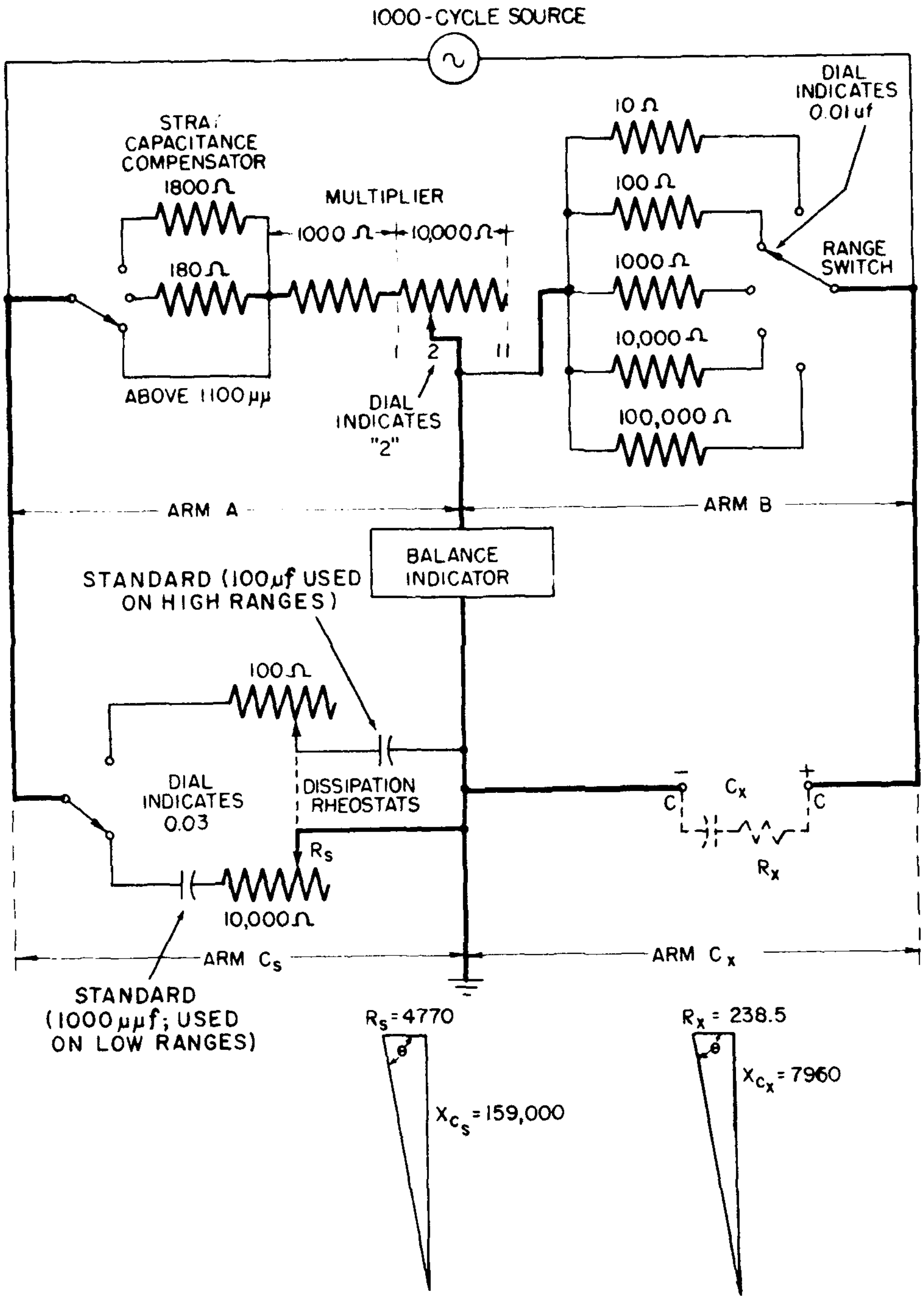

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Figure 6-3.—Capacitance bridge.

The relation between resistance, reactance, and impedance in the capacitor arms of the bridge for the preceding example is represented by the two impedance triangles in the lower position of figure 6-3. The triangles are similar but not equal.

They are not drawn to scale; the length of the base lines is exaggerated in order to show clearly the effective series resistances, R_S and R_X, in their respective arms.

Because the power factor is low (0.03), θ is almost 90°, and the impedance (hypotenuse) is assumed to be equal to the reactance (altitude) of the right triangle. The base of the triangle represents the effective series resistance in each case.

On the instrument itself, the range switch will indicate 0.01 μf, and the multiplier dial will indicate 2; the reading will therefore be 0.02 μf. That is, 0.01μf on the range switch multiplied by 2 on the multiplier dial is equal to 0.02 uf. The calibrated dissipation dial will indicate some value—for example, 0.03 (or a 3% power factor). The larger the dissipation of the capacitor under test the larger will be the value of the dissipation rheostat resistance in series with the standard.

Inductance Measurements

When the FUNCTION switch of the ZM-11/U is in an INDUCTANCE position (either L (Q) or L (D) position), the circuit shown in simplified form in figure 6-4, A, is selected by the switch.

Because this circuit is somewhat more complex than those discussed previously, the circuit is further simplified into parts B and C.

The circuit shown in part B is selected when the FUNCTION switch is in the L (D) position. This circuit is used when the dissipation, D, is less than 0.05. Arm A contains the multiplier and a fixed resistor connected in series. Arm C_S contains one of the standard capacitors and its associated dissipation rheostat connected in series (capacitance standards are used in the inductance bridge to reduce the total number of standards needed). Arm B contains one of the range resistors, and arm L_X contains the inductor of unknown inductance. Arm L_X also contains R_X, the effective series resistance of arm L_X (R_X is, of course, a part of the impedance of arm L_X).

The circuit shown in part C is selected when the FUNCTION switch is in the L (Q) position. This circuit is used when the dissipation, D, is greater than 0.05. This circuit is essentially the same as the one shown in part B, except for arm C_S. In arm C_S the shunt rheostat, R_S shunts the standard capacitor, C_S. This rheostat is positioned by means of the Q dial. Q is the merit factor of a coil; it is the ratio of the inductive reactance (X_L) to the resistance (R). It is also the reciprocal of the dissipation factor — that is, $Q = \frac{1}{D}$. As stated above D = cos θ and from the impedance triangle (Fig. 6-3) $\cos\theta = \frac{R}{Z}$. Because R is small, for all practical purposes $Z = X_L$, therefore $\cos\theta = \frac{R}{X_L}$ and

$$Q = \frac{1}{\frac{R}{X_L}} = \frac{X_L}{R}.$$

As a practical example, assume that the inductance of a high-Q coil is being determined by means of the bridge circuit shown in part B. Assume that the inductor of unknown inductance is connected in arm L_X, that the resistance of arm A is 2000 ohms (multiplier dial in position 2) and that the 10,000-ohm range resistor is in arm B. Assume also that the dissipation rheostat connected to the D dial is adjusted to balance the bridge, and that the dial indicates 0.03, which is also the power factor of the inductor under test. The capacitance of the C_S arm is 1000 $\mu\mu$f. At balance,

$$\frac{Z_{arm L_X}}{A} = \frac{B}{Z_{arm C_S}}.$$

The impedance triangles shown in figure 7-5 will be helpful in illustrating how the reactance of L_X may be determined. For a power factor of 0.03, the phase angle is above 88° and so close to 90° that, for practical purposes, X_{L_X} is equal to $Z_{arm X_L}$, and X_{C_S} is equal to $Z_{arm C_S}$ in the figure. Therefore, the preceding equation may be written as

$$\frac{X_{L_X}}{A} = \frac{B}{X_{C_S}}$$

$$\frac{\omega L_X}{A} = \frac{B}{\frac{1}{\omega C_S}}$$

$$L_X = C_S B A.$$

Where $\omega = 2\pi f$.

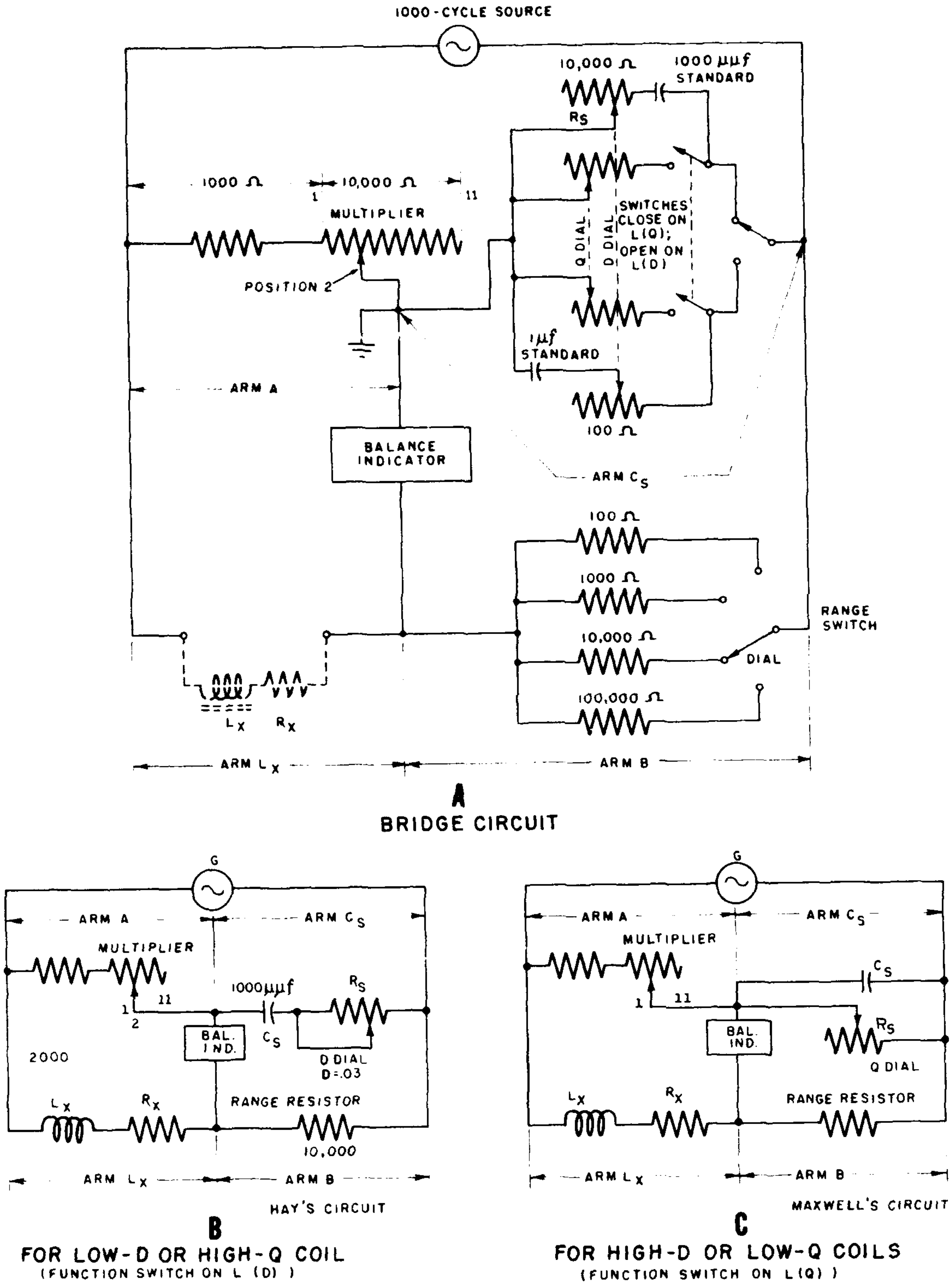

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Figure 6-4.—Inductance bridge.

Substituting the known values,

$$L_x = 1000 \times 10^{-12} \text{ X } 10{,}000 \times 2000$$

$$2 \times 10^{-2} = 0.02 \text{ h.}$$

Converting to millihenries,

$$L_x = 0.02 \times 10^3 = 20 \text{ mh.}$$

On the meter itself the range switch will be on the 10-mh position, and the multiplier dial will indicate 2. The inductance of the unknown inductor will then be 10 mh x 2, or 20 mh. The dissipation will be 0.03, as previously stated.

The relationship between resistance, reactance, and impedance in the capacitance and inductance arms of the bridge for the preceding example is represented by the two impedance triangles of figure 6-5. The calculations are:

$$X_{L_X} = 2\pi fL = 6.28 \times 10^3 \times 2 \times 10^{-2} = 125.6 \text{ ohms}$$

$$X_{C_S} = \frac{1}{2\pi fC} = \frac{10^{12}}{6.28 \times 10^3 \times 10^3} = 159{,}000 \text{ ohms}$$

$$R_X = X_L \cos\theta = 125.6 \times 0.03 = 3.77 \text{ ohms}$$

$$R_S = X_{C_S} \cos\theta = 159{,}000 \times 0.03 = 4770 \text{ ohms.}$$

An alternate inductance measuring method known as the R-L and audio signal generator method can be used to determine the inductance of a coil (fig. 6-6). This method makes use of a coil, L (unknown value) and a resistor, R (of known value) in series across the output of an audio signal generator. Voltmeters are placed in the circuit to read the voltage drops E_s, E_l, and E_r. The resistor is 3 ohms. By a careful study of the impedance triangle of figure 6-6, it can be seen that

$$\frac{E_L}{E_r} = \frac{IX_L}{IR} = \frac{X_L}{R}, \text{ and therefore } \frac{EL \times R}{E_r} = X_L.$$

For example assume that when a 1000 cycle voltage is applied the meters read E_s = 5v., E_r = 3v., and E_L = 4v. Substituting the values in the above formula, $X_L = \frac{E_L \times R}{E_r} = \frac{4 \times 3}{3}$

$= 4\,\Omega$ Thus $X_L = 4\,\Omega$.

Substituting in the formula $X_L = \omega L$ and transposing for L, $L = \frac{X_L}{\omega} = \frac{4}{6.28 \text{ X } 10^3} = 0.64$mh. Thus for the unknown coil, L = 0.64mh, where f = 1000 cycles = 10^3.

POWER MEASUREMENTS

D-c power measurements and power measurements at power frequencies are treated in Basic Electricity, NavPers 10086 (revised) and will not be repeated in this training course.

In the audio-frequency range, power-level measurements are usually expressed in decibels (db) or decibels with a reference level of one milliwatt (dbm). The technician must therefore become familiar with these units.

In the LF, MF, HF, and VHF bands, a dummy antenna and a thermocouple ammeter may be used to obtain reasonably accurate measurements of the power output of a transmitter.

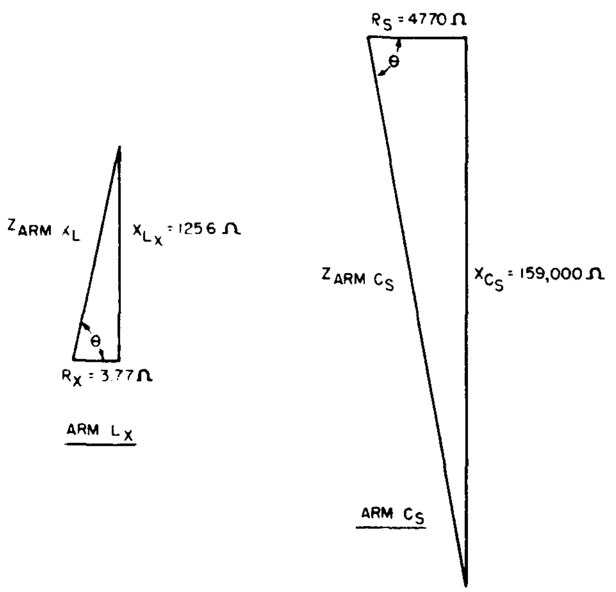

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Figure 6-5.—Impedance triangles.

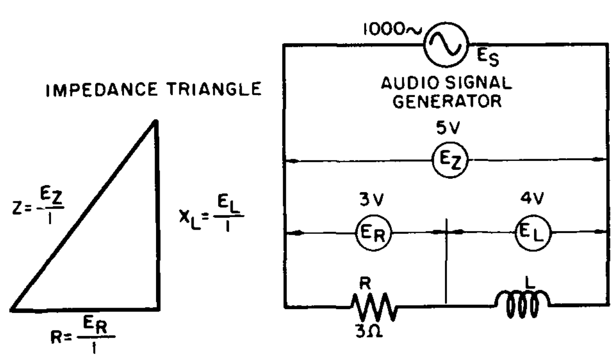

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Figure 6-6.—Alternate inductance measuring method.

In the UHF and higher portions of the r-f spectrum, special power-measuring equipments employing bolometers are used.

FREQUENCY MEASUREMENTS

It is necessary to make frequency measurements to ensure that electronic equipments remain on the assigned frequency.

Radio transmitters must be maintained on their assigned frequency (within the allowable deviation limits) in order not to interfere with other transmitters. It is also obvious that if the receiver is pretuned to a set frequency, and the transmitter is off frequency, communication may not be established. It is therefore important that a primary frequency standard be established so that frequency meters (secondary standards) may be accurately calibrated and used to keep the transmitters and receivers on frequency.

The primary frequency standard is supplied by station WWV in Washington and WWVH in Hawaii. Both stations are operated by the National Bureau of Standards. The schedule of services offered by these stations is published in Radio Navigation Aids, H.I. 205, issued by the USN Oceanographic officer.

To maintain its communication equipment on frequency, the Navy supplies good secondary frequency standards. These are discussed later in this chapter. Of course, the secondary frequency standard is of little value unless it is accurately calibrated against the primary standard.

Radar transmitters and receivers must likewise be maintained on the correct frequency if maximum use is to be made of the radar system. The components of a radar system are designed to be operated within certain frequency limits, and these frequency limits must be respected.

Interference could result if radars in the same area were operated on the same frequency; therefore, certain radars may be tuned to operate in different parts of a radar band. Except for beacon operation, a knowledge of the receiver frequency is not very important as long as the receiver is carefully tuned to the transmitter frequency.

Frequency measurements are also important in sonar testing.

FIELD-INTENSITY MEASUREMENTS

The field intensity, or strength, of a radio wave at a given point is, in most cases, a measure of the strength of the electric field component of the wave at that point. It is usually measured in terms of the number of millivolts or microvolts induced in an antenna one meter long.

Several types of test equipments for measuring field strength and interference are available to the technician. They are known generally as noise-field intensity meters. With this equipment, it is possible to measure either the RELATIVE or the ABSOLUTE magnitude of the field intensity produced by the energy radiated from an antenna. By the use of these instruments the directivity of an antenna may be determined, favorable antenna sites may be discovered, field patterns of an antenna may be plotted, and spurious radiation detected.

The measurement of relative field strength can be done with simple test equipment. It may consist of only a grid-dip meter or a pickup antenna, a tuner, a rectifier, and a microammeter.

For measuring the absolute field strength, more elaborate equipment is needed. These measurements are treated in more detail in the training courses, ET 2 and ET 1 and C.

INTERFERENCE MEASUREMENTS

A brief treatment of interference (and field-intensity) measurements is included in Basic Electronics, NavPers 10087 (revised). Instruments similar to those used in making field-intensity measurements are used. One of the simplest methods of locating the source of noise interference is to move about with the noise meter in the suspected area and listen to the audio output by means of a headset. It is often possible to locate the source of interference simply by walking in the direction that gives the largest volume of noise.

Two types of antennas are available for close work: the probe and the loop. The probe is a short wire antenna (approximately 1 ft in length) and operates by electrostatic induction; the loop (approximately 1 ft in diameter) operates by electromagnetic induction. These antennas will often permit the discovery of the individual item in an equipment that is causing the interference—for example, a sparking relay contact.

SENSITIVITY MEASUREMENTS

Receiver sensitivity measurements are made to determine whether or not the receiver is performing according to the required sensitivity

specifications. The sensitivity is the value of signal voltage (in microvolts) fed to the receiver antenna terminals, which will produce a specified power output (for example, 6 mw) at the receiver output terminals when the signal-to-noise ratio is 10:1.

Receiver sensitivity measurements are very important in that they give a good indication of how well the receiver is performing its function. These measurements are made periodically aboard ship.

The details of how the measurements are made are given later in the chapter.

RADAR PERFORMANCE MEASUREMENTS

The power output of a radar transmitter may be measured in terms of relative values or absolute values. Relative values are useful in indicating CHANGES in output power. For this purpose a suitable rectifier (for example, a crystal) may be used in a suitable circuit with a d-c meter to indicate relative power in terms of needle deflection.

If the same meter and rectifier are used each time a measurement is made, and if no defect occurs in the setup, changes in power output will be indicated. On the basis of a change in power output, corrective maintenance may be undertaken.

There are obvious disadvantages in the use of relative values such as these. When the initial reading is taken, the equipment may be operating below the operational standards set for it. The readings may vary because of some defect in the crystal or meter or because of the way the technician makes the connections. Finally, the equipment is rated in watts by the manufacturer and by the engineer who set up the performance standards, and output power readings in watts are therefore more meaningful to the technician.

Before discussing the methods of making radar power measurements, it is necessary to have a clear understanding of what is meant by PEAK power and AVERAGE power. Because a radar transmitter generates r-f energy in the form of extremely short pulses and is turned off between pulses for comparatively long intervals, there is considerable difference between the peak power and the average power.

The relationship between peak and average power is treated in Introduction to Radar, of Basic Electronics, NavPers 10087 (revised).

An understanding of the use of the DECIBEL as a unit of power gain or loss is likewise necessary before a technician can acquire a clear understanding of the various methods of making radar power measurements. This subject is treated in Basic Electronics, NavPers 10087 (revised).

Methods of Sampling Radar Power

There are three common methods of taking a sample of radar power. They include the use of the R-F PROBE, the DIRECTIONAL COUPLER, and the TEST ANTENNA. For the purpose of this chapter, only the methods of extracting power and making power readings are given; the theory of operation is left to other courses of study in the ET series.

The R-F PROBE (in older radar systems) was used extensively for power sampling. It has been largely replaced by some form of directional coupler. The r-f probe consists of a small probe (or antenna) which when inserted into the waveguide or coaxial line extracts a small amount of power. The further the probe is pushed in, the greater the amount of power pickup. Most r-f probes provide 20 db or more attenuation between the main transmission line and the probe output.

Although the probe allows the radar equipment to be operated normally during tests, it has several disadvantages. The attenuation figure (and therefore the accuracy of the readings) is affected by line reflections and reflections from nearby objects. Other disadvantages may be summarized as follows: (a) The probe penetration is critical, (b) the probe is frequency sensitive, and (c) the attenuation figure depends on the type of load connected to the probe.

The DIRECTIONAL COUPLER couples, or samples, the energy traveling in one particular direction in a waveguide. A cutaway view of one type of directional coupler is illustrated in figure 6-7. If properly used, reflected power has little effect on the accuracy of the power measurements.

The amount of energy coupled from the waveguide to the coaxial output depends on the size of the two coupling holes. A small portion of the energy flow from right to left is coupled to the probe. However, energy flow from left to right is not coupled to the probe, but is largely dissipated in the matched load.

Generally, the power available at the probe is over 20 db down from the power level in the guide—that is, when the energy is moving from right to left through the directional coupler.

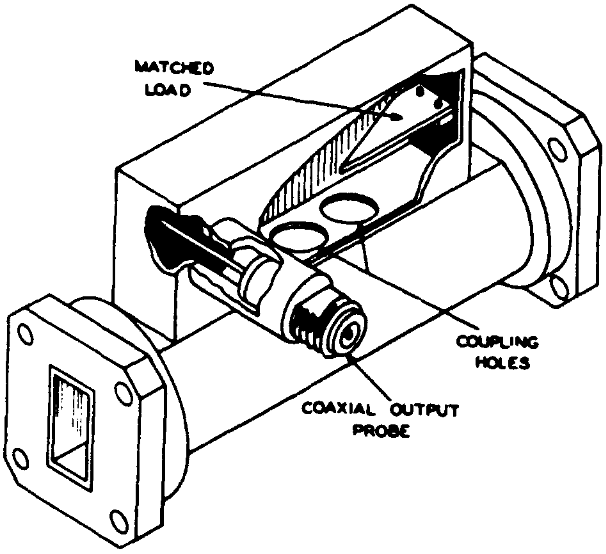

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Figure 6-7.—Cutaway view of directional coupler.

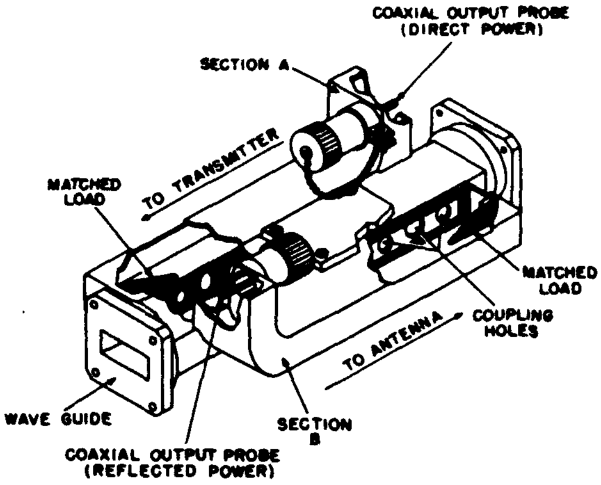

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Figure 6-8.—Cutaway view of bidirectional coupler.

This loss in power is called the ATTENUATION, COUPLING FACTOR, or DIRECTIONAL COUPLER LOSS and is stamped on the coupler. The ability of the coupler to reject energy that moves through the guide in the reverse direction is called the DIRECTIVITY.

A BIDIRECTIONAL COUPLER is used to sample direct or reflected power. A cutaway view of a bidirectional coupler is shown in figure 6-8. It consists of a straight section of waveguide, with an enclosed section attached to each side along the narrow dimension. Each enclosed section contains an r-f pickup probe at one end and an impedance termination at the other end. The sections are supplied with energy from the main waveguide through coupling holes.

The TEST, or PICKUP, ANTENNA tunes broadly to the radar band being used. It may be placed in front of the radar antenna at a distance equal to the diameter of the radar antenna and so directed that it will pick up maximum energy. The space attenuation (output from pickup antenna compared to output from radar antenna) is then about 30 db; it is generally given, or will have to be determined.

A simplified test arrangement employing a pickup horn (pickup antenna) is shown in figure 6-9. The space loss of the pickup antenna is

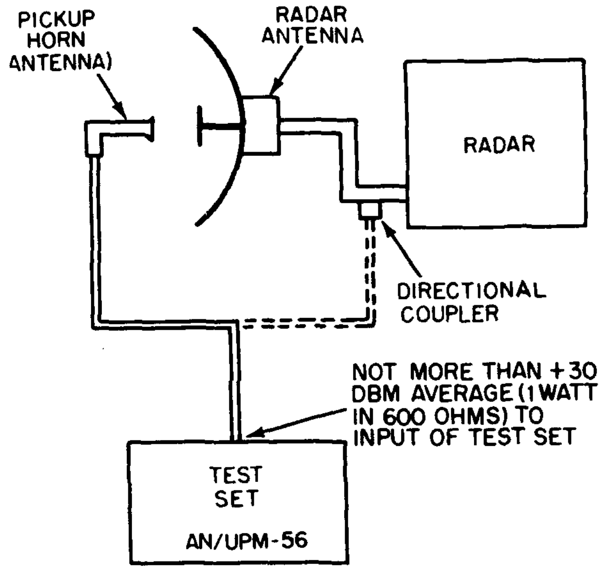

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Figure 6-9.—Simplified test arrangement employing pickup horn.

measured by comparison with the loss in the directional coupler. Once the space loss for a particular radar is determined, it is unlikely that the measurement will have to be repeated

for each system of the same type, provided the same pickup antenna location is always used and the distance chosen is the least critical.

To ensure that the antenna is placed at the least critical location, the pickup antenna is positioned where a change in its position produces a minimum change in the amount of the meter reading on the test set. This usually occurs when the pickup antenna is placed from 3 to 5 ft from the radar antenna and at a maximum power point of the antenna pattern.

In the case of the test set used in this figure, care must be taken not to apply more than +30 dbm (1 watt in 600 ohms) to the r-f input/output connector. The test set is connected as shown, first using the directional coupler and then the pickup antenna. In each case the average power of the antenna is recorded.

The loss (space loss, plus antenna loss, transmission-line loss, etc.) for the pickup antenna in conjunction with the particular radar system is the difference between the dbm dial reading on the test set meter when the test set is connected to the directional coupler and the dbm dial reading when the test set is connected to the pickup antenna, added to the db (attenuation) value of the directional coupler.

MEASUREMENTS IN RADIO FREQUENCY CIRCUITS

In d-c circuits, power is the product of the current through a component and the voltage appearing across the component. Actually, if the resistance of the component is known, the power can be determined by the use of only one instrument (ammeter or voltmeter). The three basic power formulas are

$$P = E \times I$$

$$P = \frac{E^2}{R}$$

$$P = I^2R.$$

If the resistance is unknown, it may be determined by the use of an ohmmeter or a resistance bridge.

Below the UHF band, it is usually possible to measure the effect of a-c power directly in much the same manner as d-c measurements are made. In fact, modifications of this basic procedure utilizing the thermocouple ammeter are commonly used. The following power relationship is applicable:

$$P = I^2R,$$

where P is the power delivered by the transmitter, I is the r-f current in the antenna, and R is the effective resistance (principally radiation resistance) of the antenna.

A typical circuit for determining antenna input power is shown in figure 6-10. The meter may be calibrated to indicate the square of the current. The input power is equal to the product of the meter reading and the antenna effective resistance. Several methods are used for determining the effective resistance of the antenna. They include the VARIATION, SUBSTITUTION, and BRIDGE methods.

Antenna Resistance Measurements

BASIC VARIATION METHOD.—This method of making antenna resistance measurements is illustrated in figure 6-11A.

The antenna resistance at the natural frequency of the antenna (tuning network not used—that is, L and C in ZERO positions) is determined first. The antenna is connected to ground through the coupling coil and the milliammeter, A; the shorting switch is in the CLOSED position (R_s is out of the circuit). Care should be taken to ensure that no signal is coupled to the antenna except through the coupling coil.

The r-f oscillator is then tuned to the resonant frequency of the antenna system. There should be a gradual dip in the grid-circuit milliammeter (not shown in the figure), reaching a maximum at the resonant frequency of the antenna system. If the dip in grid current

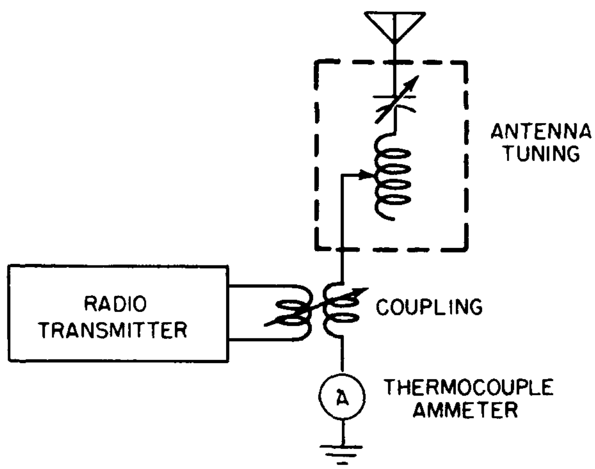

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Figure 6-10. Typical circuit for measuring antenna input power.

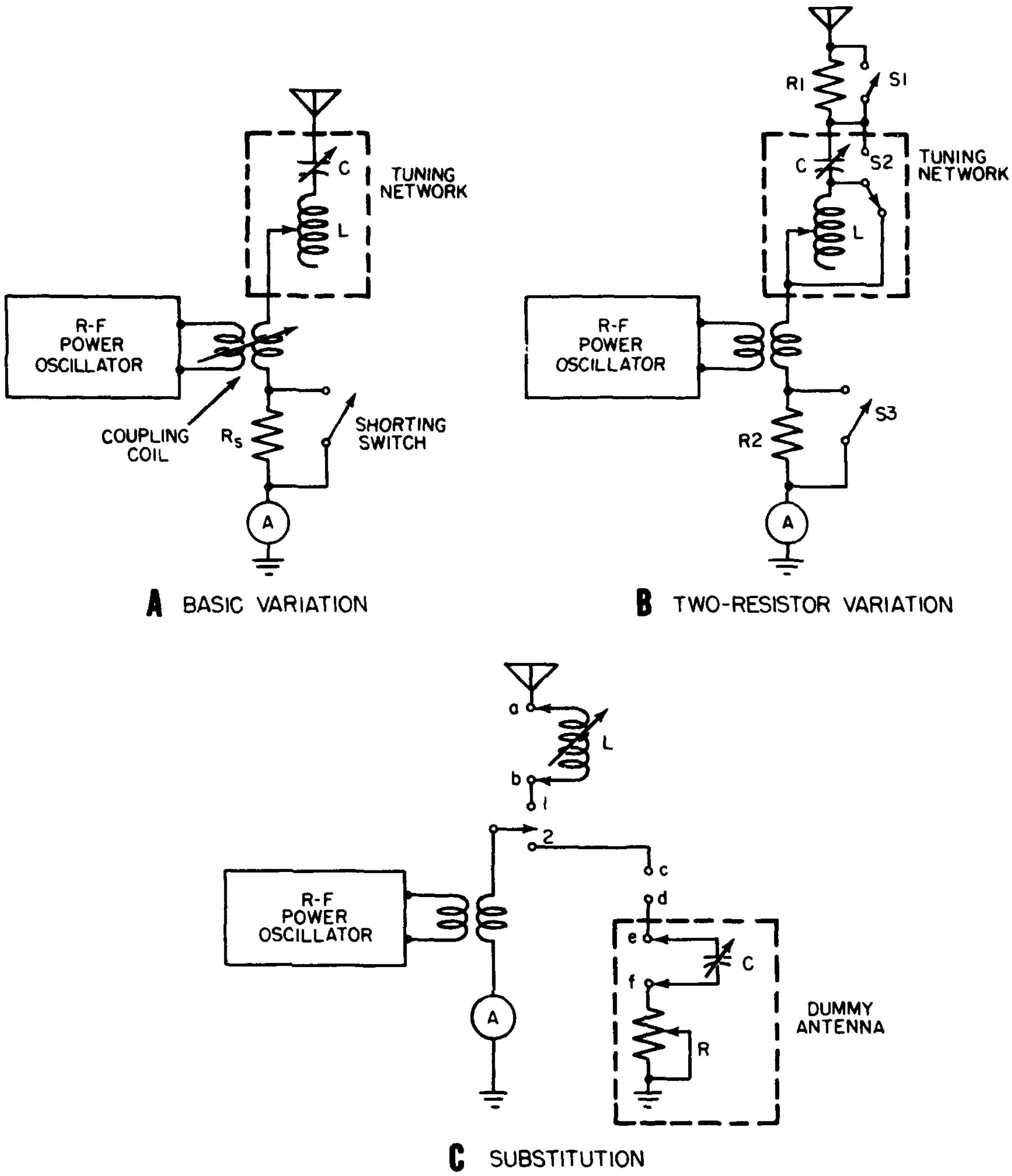

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Figure 6-11.—Methods of making antenna resistance measurements.

is too abrupt, the coupling should be reduced. At the instant of lowest grid-current reading, the antenna milliammeter reading (I_a) should be maximum. The precision resistor, R_s, is next inserted in the antenna circuit (by opening the shorting switch), and the antenna current, I_s, is again read. During these readings no adjustments should be made in the coupling (the

voltage induced in the antenna secondary should be constant). The antenna resistance, R_a, is determined by the formula,

$$R_a = \left(\frac{I_s}{I_a - I_s}\right) R_s.$$

Example: Find the antenna resistance if the antenna current is reduced from 2.5 amperes to 1.0 ampere after inserting a standard resistance of 60 ohms.

$$R_a = \frac{1.00}{2.50 - 1.00}(60) = 40 \text{ ohms}.$$

The frequency of transmission is not necessarily the same as the natural frequency of the antenna.

The resistance of the antenna at the frequency of transmission is next determined. The tuning network is connected into the circuit to resonate the antenna to the frequency of transmission. The shielding eliminates stray coupling paths.

The antenna is tuned to resonance (by means of the tuning network) at the frequency of transmission, and the current readings are taken with R_s out of the circuit and with R_s in the circuit, as was done previously. R_a is computed the same as before.

The same procedure should be repeated for frequencies above and below the natural resonant frequency of the antenna and a graph (essentially a straight line) of antenna resistance vs frequency plotted. Antenna resistance without the tuning network should not vary greatly from the antenna resistance with the tuning network.

TWO-RESISTOR VARIATION METHOD.—This method of making antenna resistance measurements is helpful in determining if stray capacitive paths to ground are shunting the system. Although a variable inductor and capacitor are shown (fig. 6-11B), it is likely that only one or the other would be used. The inductor or capacitor should have calibrated dials. Two standard resistors are used instead of the single resistor that was used in the previous method. One resistor is located on the grounded side of the antenna transformer secondary; the other is located on the antenna side of the tuning network.

At the beginning of the test, both resistors are shorted out of the circuit, and the antenna circuit is tuned to the frequency of transmission (to the frequency of the oscillator). The oscillator output is then adjusted to produce the desired deflection, I_a, on the r-f milliammeter in the antenna circuit. No readjustment of the output should be made during the remainder of the test.

Switch S1 is then opened to insert R1 into the antenna circuit, and the antenna current, I_a, noted.

The antenna resistance, R_a, is computed by the formula that was given previously.

Next, S1 is closed to short out R1, and S3 is opened to place R2 in the antenna circuit. The antenna resistance, R_a, is again computed by means of the formula.

If the two values of R_a do not agree, there is appreciable stray capacitance between the measuring circuit and ground or elsewhere. Proper grounding, shielding, and arrangement of the components will permit the two readings to be essentially the same.

The reactance of the antenna at the frequency of transmission may be determined by noting the value of L or C that is required to resonate the system. If C is required, the reactance of the capacitor will be

$$X_c = \frac{1}{2\pi fC}$$

The antenna reactance, X_L, will have the same magnitude as X_c. If L is required to resonate the system, the reactance of the inductor will be

$$X_L = 2\pi fL.$$

The antenna reactance, in this case, X_c, will have the same magnitude as X_L.

Substitution Method.—This method of making antenna resistance measurements is illustrated in figure 6-11C. In this method, the antenna is replaced by equivalent amounts of reactance and resistance (a dummy antenna). Before making the resistance measurements, the antenna system is made resonant at the operating frequency. The oscillator should be well shielded and a fairly high energizing current should flow in the antenna circuit.

After these conditions are established, the adjustment of the antenna tuning element must not be disturbed throughout the remainder of the measurement procedure.

The antenna current is noted when the switch is in position 1. The switch is then placed in position 2. If a coil is used to resonate the antenna, as indicated in the figure, a capacitor will be used in the dummy antenna. If a capacitor is used to resonate the antenna, an inductor will be used in the dummy antenna. The antenna tuning element (inductor in this case) is then connected between points C and D, and the capacitor is tuned to resonance, as indicated by a maximum deflection of the milliammeter. The resistance of R is then varied until the meter reads the same as it did when the antenna was connected in the circuit. The resistance of R is equal to the antenna resistance, and the reactance of C is equal to the reactance of the antenna circuit (with the coil shorted out) at the resonant frequency.

The R-F BRIDGE METHOD (previously discussed) may be used in determining the impedance of an antenna. This method is both rapid and accurate, (if shielding is sufficient and if the connections are properly made). The exact method of making the measurements with a bridge depends on the type of bridge used.

Antenna Circuit Power Measurements

R-F POWER METERS may be used to obtain a direct reading of the power output of a transmitter when a high degree of accuracy is not required and the power output is less than 500 w. With proper termination of the transmission line, the standing-wave ratio will be negligible, and essentially all of the power will be absorbed in the power meter.

There are several indirect methods of measuring r-f power—for example, the lamp-load, resistor-load, and bolometer methods.

In the LAMP-LOAD METHOD a pair of identical lamps are placed side by side. One lamp is fed by the r-f source, and the other is fed by a d-c source through a potentiometer. An ammeter is connected in series with the lamp fed by the d-c source, and a voltmeter is connected across the lamp.

The potentiometer is varied until the lamp fed from the d-c source has the same brilliancy as that of the lamp fed from the r-f source. The d-c and r-f power dissipated in the lamps are then equal. All that is necessary to determine the power dissipated in the lamp connected to the r-f source is to multiply the ammeter reading by the voltmeter reading.

To make the readings more accurate, a photoelectric cell and a sensitive meter photographic exposure meter) may be used to determine when the lamps have the same brilliancy. It is assumed, of course, that the transmission line feeding the r-f energy to the lamp is properly terminated in the lamp.

In the RESISTOR-LOAD METHOD of measuring r-f power the temperature rise of a noninductive resistor fed by the r-f power is determined by means of thermocouples placed in a stream of air that is blown over the resistor. This method is somewhat involved in that the rate of air flow and the temperature rise must be determined before the power dissipation can be calculated.

BOLOMETER METHODS of measuring r-f energy, especially in the UHF range, are becoming standard procedure. The bolometer is a loading device that changes in resistance as the power dissipated in it changes. The two main types of bolometers are the thermistor and the barretter. Their changes in resistance with temperature change are opposite. When the thermistor dissipates more power (increased temperature) its resistance decreases; when the barretter dissipates more power, its resistance increases. (The use of the thermistor in making power measurements is described in Chapter 7.

Regardless of which type of bolometer is used, the method of making power measurements is essentially the same. The resistance of the bolometer is measured before and after the application of r-f power. A d-c source of power, which may be varied, is then connected to the bolometer, and the power is adjusted to give the same change in bolometer resistance as was obtained when r-f power was applied. The readily measured d-c power is equal to the r-f power. A bridge arrangement calibrated in units of power is commonly used along with the necessary attenuation devices. The thermistor is more widely used because of the high degree of precision that can be obtained, especially when compensating thermistors are used.

Because of the low power that the thermistor is capable of dissipating (1 mw is standard), the power must be attenuated before it is applied to the thermistor bridge. The amount of attenuation must be accurately known before the r-f power being measured can be determined.

Frequency Measurements

RADAR.—frequency measurements involve transmitter frequency and receiver frequency measurements.

The radar transmitter must operate within its assigned band of frequencies because radar beacon stations will respond only to signals within an assigned frequency range, and because the waveguide tuning adjustments cover only a limited range of frequencies. Also, two radar transmitters operating in the same band could cause serious interference.

The radar receiver must operate at the same frequency as the transmitter. A knowledge of the receiver frequency is not so important as long as the receiver is tuned exactly to the transmitter frequency.

Radar transmitter frequency measurements are often made with a combination frequency and power meter—for example, Frequency-Power Meter TS-230B/AP, a functional block diagram of which is shown in Chapter 7, figure 7-28A. An exploded view of the wavemeter is shown in part B, and the r-f assembly is shown in part C. The open-circuited coaxial transmission line (in the wavemeter) is coupled to the waveguide in the meter by means of a probe antenna. The micrometer FREQ control (fig. 7-28) varies the length (and thus the resonant frequency) of the resonant coaxial line comprising the wavemeter (fig. 7-28B). The motion of the drive can be accurately calibrated in terms of resonant frequency. When the wavemeter is in resonance, more energy is extracted from the waveguide, leaving less to be absorbed by the power thermistor; thus, there is a decrease in the meter, M, reading. (The bridge approaches a balance when the thermistor absorbs the least r-f energy.) The setting of the micrometer can then be translated into frequency by reference to the calibration chart inside the front cover of the meter.

This meter is designed to measure the frequency of unmodulated and pulsed signals in the range from 8500 to 9600 mc. It is suitable for use in a temperature range between -40°F and +131°F.

The following is a brief summary of the procedure for making a frequency measurement, using the Frequency-Power Meter TS-230B/AP. The meter is turned on, adjusted, and calibrated as outlined in the instruction book. It is not necessary to have the meter adjusted to precisely zero when frequency alone is being measured. The ADJ zero control is next set to the position that makes the meter read close to zero, and the meter is connected to the radar system by means of the connector or adapter furnished with the meter.

The radar transmitter is then turned on, and the input attenuation control is adjusted to give a meter reading between 50 and 100 μa at M (fig. 7-28A).

The FREQ control is moved to an initial setting of 9600; then it is turned slowly clockwise until the meter reads the exact minimum. This should be done slowly because there is a slight time lag in the change in resistance of the thermistor in the bridge circuit.

The FREQ setting is recorded, and the calibration curve is used to obtain the frequency in megacycles corresponding to the micrometer (FREQ dial) setting.

The following sample calculation is taken from the instruction book. For purposes of illustration, the micrometer setting at resonance is assumed to be 8555.0. From the sample calibration chart (fig. 6-12) the point on the curve corresponding to 8555 mc (8.555 kmc) corresponds to 13 mc on the frequency deviation axis. The frequency is calculated by adding 13 mc to 8555 mc to give 8568 mc. Frequency measurements are also included under the section on echo box in the next chapter.

RADIO.—It is very important to keep Navy transmitters on their assigned frequencies. To aid the technician or operator in keeping the transmitters within the frequency tolerances, the Navy provides accurate frequency meters. These meters must be calibrated periodically against the primary standard frequencies transmitted by the U. S. Bureau of Standards. These primary frequency standards are transmitted continuously, day and night.

Where extreme accuracy is not of prime importance, as in making preliminary adjustments or for general experimental work, rapid frequency checks may be made with the simple resonant-circuit wavemeter of the absorption type.

The ABSORPTION-TYPE WAVEMETER, the grid dip meter, and secondary frequency standards are discussed in Basic Electronics NavPers 10087 (revised).

A REACTION-TYPE WAVEMETER may also be used. In this type of wavemeter the indicating device is in the circuit under test; otherwise, the setup is essentially the same as that used

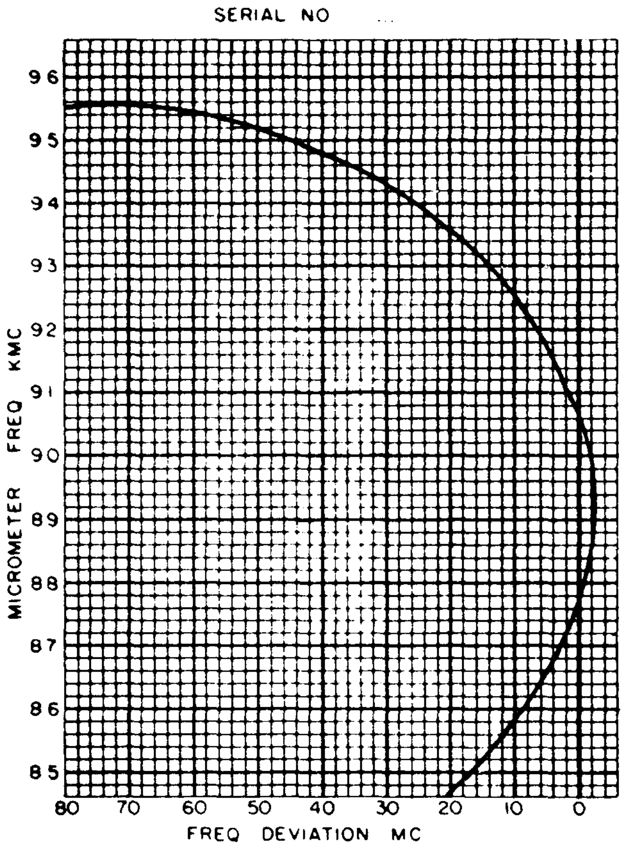

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Figure 6-12.—Sample calibration chart.

with the absorption-type wavemeter. The reaction-type wavemeter absorbs very little energy from the source and is therefore advantageous when the frequency of low-power sources is being measured.

Where great accuracy is needed, oscillating frequency standards (FREQUENCY METERS) are used. These instruments are similar to signal generators, but are more stable and accurate; however, they have lower output than a signal generator. The frequency meter is used to measure frequency and to tune transmitters and receivers to the desired frequency. As has been mentioned, they must be compared with the primary frequency standard transmissions of WWV (Washington) or WWVH (Hawaii) at frequent intervals.

A HETERODYNE type frequency meter (one of the LM series) used extensively on small craft is shown in figure 6-13. Several models of this meter have been built. These models are similar except for the power supply and some minor mechanical differences. The LM-21 frequency meter covers the band of frequencies from 125 to 20,000 kc. This equipment has accuracies within 0.02 percent in the 125- to 2000-kc band and within 0.01 percent in the 2000- to 20,000-kc band.

Two oscillators are used: (1) crystal oscillator and (2) heterodyne oscillator. The crystal oscillator is used to calibrate the heterodyne oscillator at several different points over the entire band covered by the frequency meter. The LM-21 also contains an a-m detector, an audio amplifier, and a modulator.

The fundamental frequency of the crystal oscillator is 1000 kc. However, the oscillator output has a high harmonic content. A small trimmer capacitor is placed across the crystal so that if the crystal frequency changed, an adjustment can be made to keep the crystal frequency close to 1000 kc. Most of the frequency-determining components, including the crystal, are hermetically sealed to keep out moisture and dirt.

The band of frequencies measured by the LM-21 is covered in two ranges. The heterodyne oscillator has two continuously variable ranges that may be selected by the frequency band switch. In the LOW position a fundamental range of 125 to 250 kc is used. By calibrating the first, second, fourth, and eighth harmonics of this range, continuous coverage from 125 to 2000 kc is obtained. In the HIGH position of the switch, the fundamental range of 2000 to 4000 kc is calibrated over the first, second, fourth harmonics, and part of the fifth harmonic to provide continuous coverage through the range of 2000 to 20,000 kc.

The LM-21 frequency meter can be used to tune transmitters and receivers (both c-w and m-c-w) and to determine the frequency of a received signal. Figure 6-14 shows a block diagram of the frequency meter when it is used to calibrate the heterodyne oscillator with the crystal oscillator.

The output of the heterodyne oscillator is coupled to the grid of V102. Tube V102 is used as a crystal oscillator and mixer. The two oscillator frequencies beat together and the difference frequency is developed across choke L104. An audio amplifier, V103, amplifies the beat note and supplies it to a set of headphones. If a beat note is heard, the corrector, C102, is adjusted until a zero beat is obtained. Thus the heterodyne oscillator is corrected to the crystal

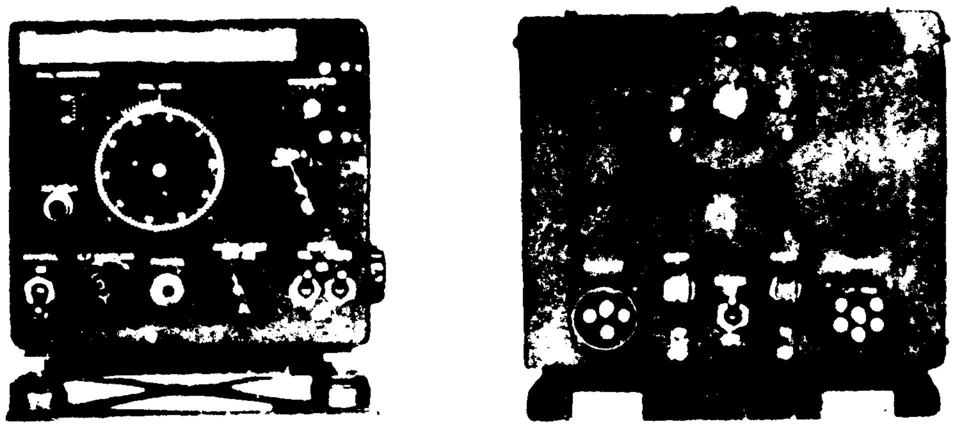

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Figure 6-13. —LM-21 frequency meter.

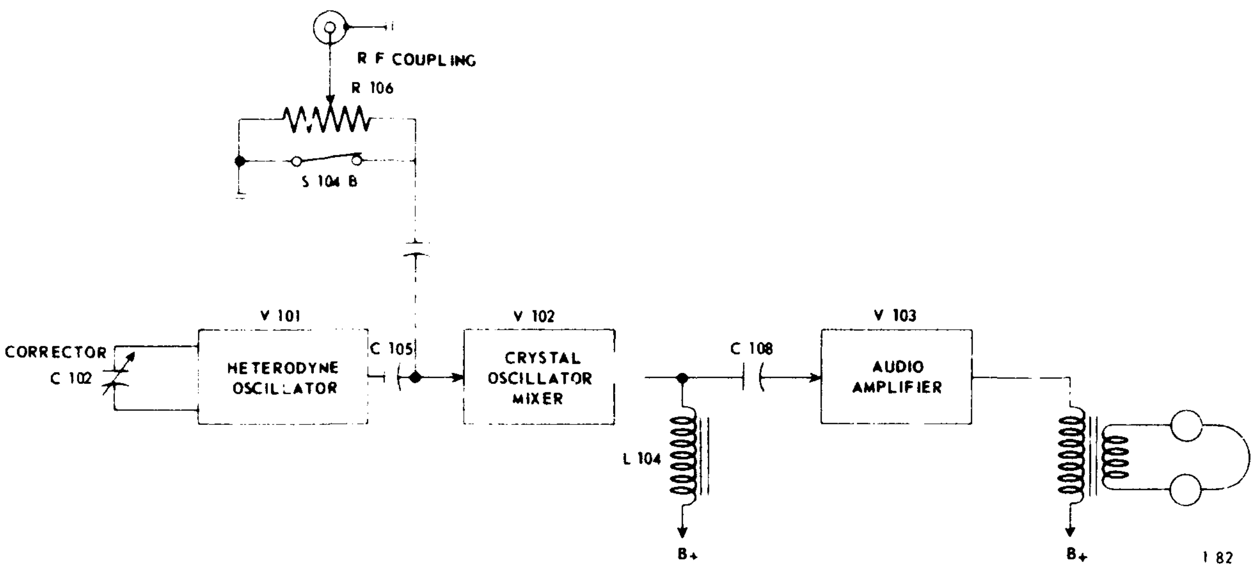

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Figure 6-14. —Block diagram of LM-21 frequency meter when calibrating the heterodyne oscillator.

check point nearest the frequency to be measured, as shown in the calibration book. During the calibration procedure, r-f coupling R106 is grounded by a section of S104 to prevent interference from external r-f signals.

Figure 6-15 is a block diagram of the LM-21 frequency meter when it is used to tune a receiver or a transmitter to a given frequency. The modulation and crystal switches are in the OFF position for this operation. When a receiver is tuned, the heterodyne oscillator output is coupled through capacitors C105, C106, and potentiometer R106 to the receiver. The beat-frequency oscillator of the receiver is turned on, and the receiver is tuned until a zero beat is heard in the output of the receiver (not shown in the figure). It is assumed that the beat-frequency oscillator frequency is centered in the r-f band pass before the receiver tuning is accomplished.

When a transmitter is tuned, a portion of the transmitter oscillator signal is coupled into the

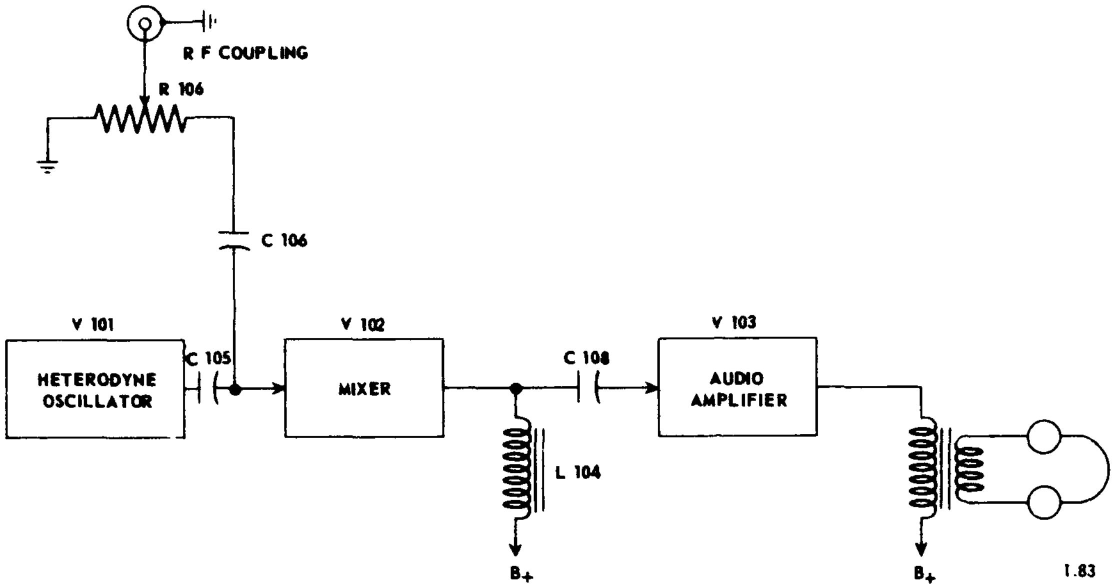

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Figure 6-15.—Block diagram of the LM-21 frequency meter when tuning a transmitter or a receiver.

requency mete~ through R106 and C106 to the ıixer tube, V102. This signal from the transnitter is mixed with the output of the heterodyne ›scillator. The difference frequency is developed ıcross L104 and amplified by V103. The output ›f V103 may be fed to a phone jack in the switchng system for convenience because the transnitter may be located at a distance from the requency meter. A zero beat occurs when the ransmitter frequency is the same as the freıuency of the heterodyne oscillator.

Figure 6-16 shows a block diagram of the .M-21 frequency meter when it is used to tune ın m-c-w receiver. The modulation switch is)N and the crystal switch is OFF. In this ar·angement, the crystal oscillator-mixer is not ısed in the circuit. When the modulation switch s ON, the audio amplifier, V103, becomes a ›00-cycle audio oscillator. The output of the ıudio oscillator is fed to the suppressor grid of he heterodyne oscillator where it modulates the ·-f signals generated by this tube. The output is ed to the m-c-w receiver (not shown in the igure). No zero beat is heard. Instead, the ·eceiver is tuned for maximum output of the ›00-cycle modulating signal. The r-f coupling :ontrol, R106 is adjusted to produce the desired ›utput signal.

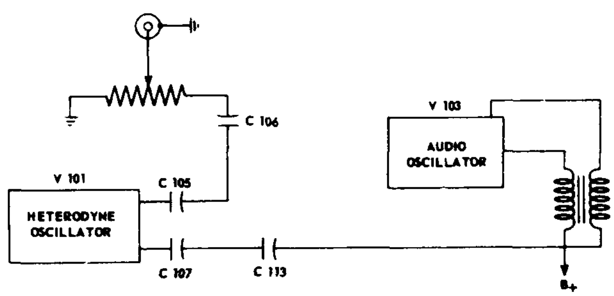

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Figure 6-16.—Tuning an m-c-w receiver with the LM-21 frequency meter.

The power supply is a separate unit. This unit supplies the a-c filament voltage and the relatively high d-c plate voltage. The plate voltage is regulated so that the output frequency is stable, regardless of variations of the line voltage to the power supply.

Other types of heterodyne frequency meters are the LR, the OCP, the TS-186/UP, and the TS-535/U.

A COUNTER type frequency meter (fig. 6-17), Electronic Counter 524C/D (Hewlett-Packard), can measure frequencies from 10 cps

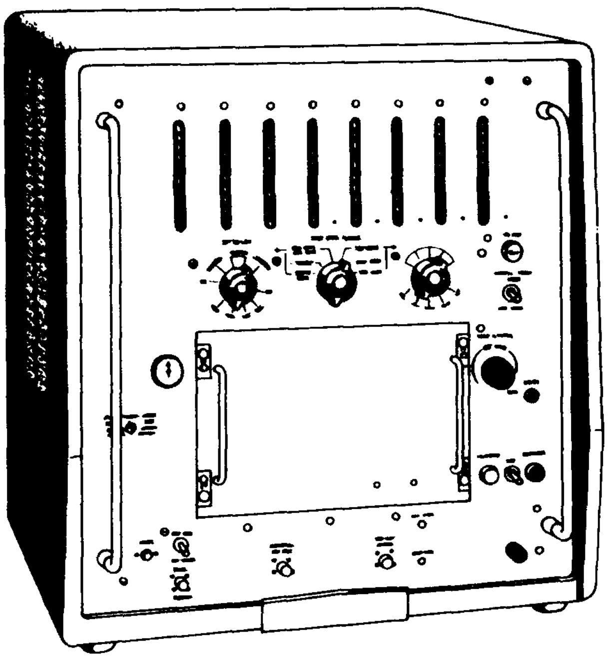

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Figure 6-17.—Electronic counter, 524D.

to 10.1 megacycles and display the readings in digital form on an eight-place indicating system. In addition to making direct frequency measurements, the counter can measure periods (0 cps to 100 kc), frequency ratios and total events. A self-check feature enables an operator to verify instrument operation for most types of measurements. The internal oscillator is stable within 5 parts of 10^8 per week. Thus these counters make good secondary frequency standards.

To increase the range of measurement, seven accessory plug-in units (not shown) are available. Frequency Converter Units, Models 525A, B, and C, increase the frequency range from 10.1 to 100 mc, 100 to 220 mc, and 100 to 510 mc respectively. Video Amplifier unit 526A increases the basic set sensitivity to 10 mv in the range of from 10 cps to 10.1 mc; Time Interval unit 526B permits measuring time intervals from 1 μsec to 10^7 seconds; Period Multiplier unit 526C extends the period measurement range up to 10,000 periods of unknown frequency; and Phase unit 526D permits measuring phase angle with an accuracy approaching ±0.1°. In addition to the plug-ins, the Model 540B Transfer Oscillator extends, as a companion instrument, the frequency range up to 12.4 megacycles (10^9).

Measuring Frequency—The basic circuit arrangement of the Electronic counter is shown in figure 6-18. For frequency measurement the signal is fed through a Signal Gate to a series of digital type counters. A precision time interval obtained from the Time Base Section opens and closes the Signal Gate for an extremely accurate period of time, for example, 1 second. The counters count the number cycles entering through the gate during the 1-second interval and then display the total. The answer is read directly as the number of kilocycles occurring during the 1-second interval. The period of time the Signal Gate remains open is set by the FREQUENCY UNIT switch (not shown). For each position of the FREQUENCY UNIT switch the illuminated decimal point is automatically positioned so that the answer is always read directly in kilocycles. The answer is automatically displayed for a period of time determined by gate time or the setting of the DISPLAY TIME control on the front panel, whichever is greater.

Measured Period—To measure a period or time interval the application of the two signals reverses as shown by the doted lines in figure 6-18. The period or time interval to be measured is connected to open and close the Signal Gate while one of the standard frequencies from the Time Base Section is passed through the Signal Gate to the counters. When measuring period, one cycle of the incoming signal opens the gate, the next cycle closes it. The number of cycles of the standard frequency from the Time Base that occurred during the period are then indicated on the counters. The standard

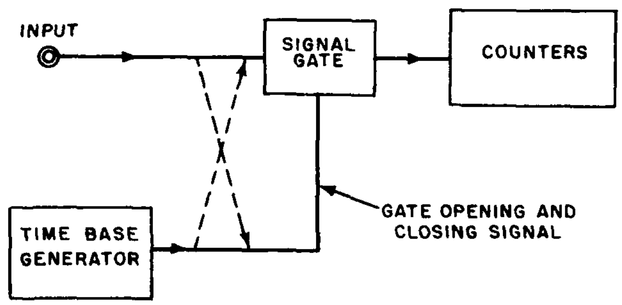

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Figure 6-18.—Basic diagram of the 524D.

frequencies obtained from the Time Base have been selected so that the answer to the measured period will always be displayed in direct-reading units of time: seconds, milliseconds, or microseconds.

Provision is also made in the circuit to permit measurement of the average of 10 periods of the unknown frequency. Higher accuracy can thus be obtained than with single period measurements.

The accuracy of frequency measurements is determined by an internal oscillator and by a possible error of ± 1 count that is inherent in the gate and counter type of instrument. At low frequencies, greater accuracy can be obtained by measuring the period of the signal than by measuring the frequency directly.

The block diagram (fig. 6-19A) shows the circuit arrangement of the basic counter when measuring frequencies in the range of 10 cps to 10.1 mc. To measure frequencies up to 510 mc, one of three frequency converter units is required (fig. 6-19B). As stated above, the 525C Frequency Converter unit is used between 100 and 510 mc. In these frequency converters the input signal is mixed with a harmonic of 10 mc so that the difference between the signal and the harmonic is not more than 10.1 mc. The difference frequency is counted and displayed by adding the count displayed by the counter to the known 10 mc harmonic.

All three frequency converters have tuning systems to indicate the correct mixing frequency. However, if the mixing frequency is within 1 mc of the unknown frequency, there is a possibility of two answers, for you may not know whether to add or subtract the displayed reading from the mixing frequency. In such cases, make additional measurements using the two adjacent mixing frequencies to determine the unknown frequency. When making the final measurement choose a mixing frequency which is at least 100 kc away from the unknown.

When measuring frequency, the counter will count sine waves, rectangular waves, and positive pulses. To measure the frequency of negative pulses, adjustment of a FREQUENCY sensitivity control is necessary. This control is a screwdriver adjustment located on the front panel.

When the counter is set for PERIOD measurements, the time base and the signal input circuits are interchanged from their frequency measurement positions (fig. 6-19C). With the circuits so connected, the counters count the output of the time base for the period of the unknown input signal. Thus the standard frequencies generated in the time base are used as units of time to measure the unknown period in terms of microseconds, milliseconds, or seconds.

The accuracy of period measurements is largely determined by the accuracy with which triggering occurs at the same point on consecutive cycles of signal voltages having a slow rate-of-rise. Nore that when the signal-to-noise ratio improves, the triggering accuracy also improves. Averaged over ten periods, the single-period error is reduced by a factor of ten. If you use the 526C Period Multiplier unit, the error is reduced an additional factor of ten for each factor of ten you extend the measurement. The accuracy of triggering is considerably improved when the waveforms being measured have a fast rise time. For example, you can obtain a significant reduction in error if you apply square waves instead of sine waves to the input.

In order to follow the slowest-changing waveforms, the period measurement input circuits are direct-coupled and are adjusted to trigger at the zero-volt crossing of a negative-going voltage. Thus any d-c component in the input signal will shift the triggering level so that the maximum slope no longer occurs at the zero-volt level, resulting in a loss of accuracy. If the d-c component is large enough, there may be no triggering at all. An external generator can be used in place of the time base generator for period measurements.

The counter can be used to measure the RATIO of two frequencies. The higher frequency is passed through the signal gate to the counters and is counted for a period of time determined by either one period or ten periods of the lower frequency, which controls the opening and closing of the gate (fig. 6-19D).

Ratio measurement accuracy is determined by the same factors as period measurement accuracy: consistency of triggering by the lower input frequency and the inherent error of ± 1 count of the higher frequency. The 526C Period Multiplier unit is used to reduce the error by extending the number of periods of the lower frequency over which the measurement is made. For each factor of ten the measurement is extended, the error is decreased by a factor of ten.

Although the time base generator is not used during ratio measurements, you cannot make

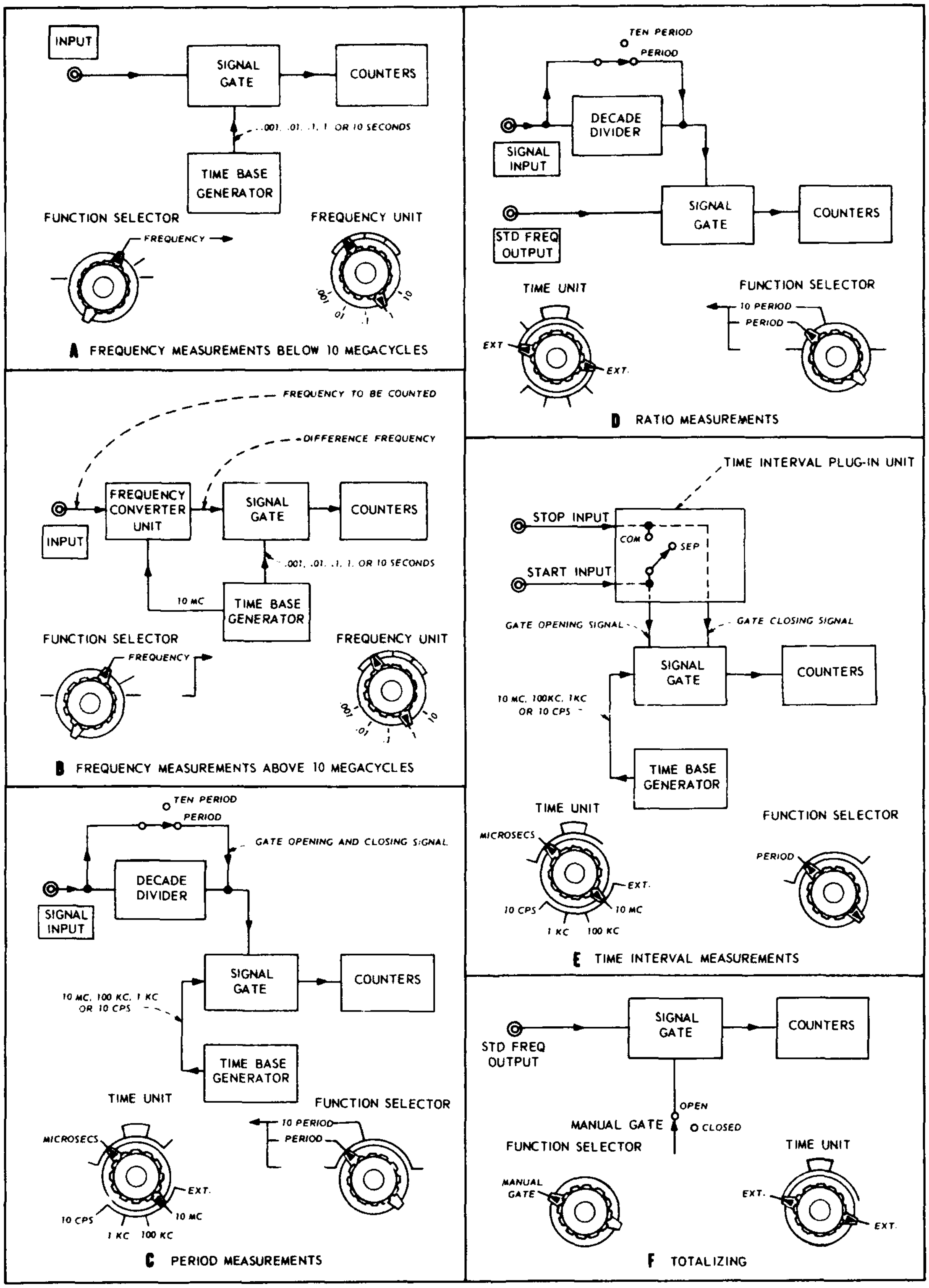

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Figure 6-19.—Test measurements, block diagram.

ratio measurements if the time base generator is not operating. The counter has a holdoff circuit which disables the signal gate if the time base generator fails.

To make TIME INTERVAL measurements (fig. 6-19E), the 526B Time Interval unit must be installed. Time interval measurements are similar to period measurements except that the points on the signal waveforms at which the measurement starts and stops are adjustable. The adjustable threshold feature allows you to make measurements from one part of the same waveform or to use separate waveforms as start and stop signals.

As in the case of period measurements, the input signals control the opening and closing of the gate while the standard frequencies are passed to the counters (fig. 6-19E). Thus the accurate frequencies generated in the time base are used as units of time to measure the unknown interval in terms of microseconds, milliseconds, or seconds.

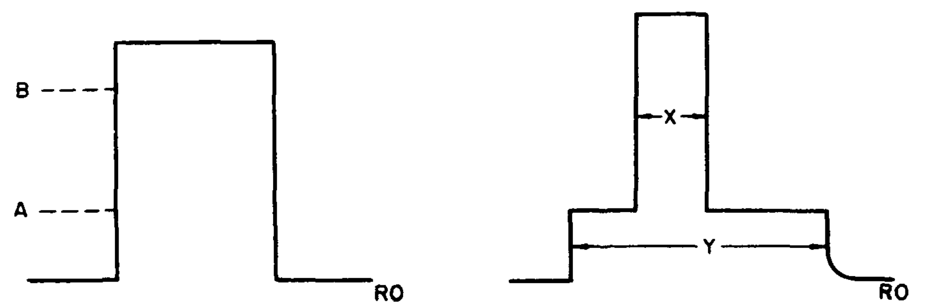
The threshold-selecting controls adjust the start and stop channels so that they will be actuated only by signals of predetermined polarity, amplitude, and slope. Time interval measurements begin when the start signal crosses the selected start threshold value in the selected direction and end when the stop signal crosses the selected stop threshold value in the selected direction. The threshold controls are only approximately calibrated, and in some applications you will have to take special precautions in order to obtain the desired interval.

If you use an uncomplicated waveform as the start and/or stop signal, the setting of the threshold controls is not critical. For example, if you use a sharp pulse like that shown in figure 6-20A, there will be little difference whether the measurement begins at point A or B. However, if you use a more complex waveform like that shown in fig. 6-20B to measure the interval X, set the threshold controls near zero as a preliminary adjustment. As you adjust first the start and then the stop threshold controls, you will notice definite changes in the measured time interval. Thus you know that the start and stop thresholds are above the step and that the indicated time interval is actually X.

It is highly desirable to examine both start and stop signals on a d-c coupled oscilloscope before you attempt a measurement. In this way you can determine that no spurious signals exist, and you will know how carefully you must set the threshold controls.

The 526B Time Interval unit may also be used as a high-speed totalizer capable of counting at a maximum rate of 10.1 million events per second. The basic circuit arrangement is indicated in figure 6-19F.

With a 526D Phase unit plugged into the counter, the phase angle between two signals of identical frequency, in the range from 1 cps to 20 kc, may be measured. This unit is useful for investigating, at various points in a circuit, the phase a signal has with respect to the phase it had at the input. Connect the reference signal to the REFERENCE INPUT, and the signal whose



A SIMPLE WAVEFORM SHOWING TWO POSSIBLE VOLTAGE LEVELS AT WHICH A TIME INTERVAL MEASUREMENT MAY BE STARTED

B TWO POSSIBLE TIME INTERVAL MEASUREMENTS OF A SINGLE COMPLEX WAVEFORM

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Figure 6-20.—Time interval waveforms.

phase is under investigation to the UNKNOWN INPUT. If the frequency of the signal is 400 cps ±4 cps, phase angle is read directly in tenths of a degree. For a signal of some other frequency in the rated range, the information is read in time units, with resolution up to 0.1 μsec. For all phase measurements, set the phase unit PHASE/PERIOD switch to PHASE, the REFERENCE LEAD/LAG switch to the type of measurement desired, and the counter FUNCTION SELECTOR to PERIOD.

In general, circuit action for a phase measurement is similar to that for a time interval measurement. Trigger circuits in the Phase unit supply the pulses which open and close the signal gate in the counter. Arrangement of the circuits will be similar to that shown in figure 6-19E, for time interval measurements.

A recommended method of TUNING RADIO RECEIVERS USING A FREQUENCY COUNTER has been included in the EIB, No. 569. This method will soon become the accepted nrocedure for all such tuning.

The latest recommended frequency standard AN/URQ-9 (not shown) consists of three fixed frequencies. This frequency standard is a highly stable, multiple-purpose frequency standard designed for continuous-duty use aboard ship and at shore facilities. It provides three output frequencies, 5.0 mc, 1.0 mc, and 100 kc, and a regulated power output of 26.5 volts d-c at 0.5 amp for use by other equipment. The set can be used for laboratory frequency measurements and to drive precision timing devices such as a time comparator.

Receiver Sensitivity Measurements

RADAR.—The loss of radar receiver sensitivity has the same effect on reducing the range as a decrease in transmitter power. For example, a 6-db loss in receiver sensitivity shortens the effective range of a radar just as much as a 6-db decrease in transmitter power. Such a drop in transmitter power may be easily detected, but a comparable drop in receiver sensitivity is not so easy to detect unless accurate measurements are made.

A sensitive receiver is one that can pick up weak signals. The minimum discernible signal (MDS) is the weakest signal that produces a visible receiver output above the noise level of the receiver.

In the microwave range of operation, virtually all of the noise originates within the receiver. Atmospheric and manmade noise or static is normally too small to be considered.

Not all receiver noise originates in electron tubes. For example (because of the heat in the circuit conductors) there are certain amounts of random motion of the electrons other than the motion associated with the signal current. These motions produce voltages within the conductor that likewise vary in a random manner. The frequencies with which these voltages vary are distributed throughout the r-f spectrum and appear as noise in the receiver.

The power in watts developed by this form of noise is given by

$$\text{noise power} = KT\,\Delta F,$$

where K is Boltsmann's constant (1.37×10^{-23} watt-seconds per degree Kelvin), T is the temperature in degrees Kelvin (C° + 273), and ΔF is the bandwidth ($f_2 - f_1$) in cycles per seconds. Frequencies f_2 and f_1 are the upper and lower noise frequency limits (frequencies at which the noise voltage falls to 0.7 of the maximum).

This formula shows that thermal-agitation noise varies directly as the temperature and the bandwidth. In a theoretically perfect receiver having no noise except thermal-agitation noise, this noise could be considered as a voltage across the antenna terminals, and the power represented could be calculated on the basis of temperature and bandwidth.

In practice, the noise generated in a receiver is not limited to thermal-agitation noise. Additional noise sources are carbon resistors, which generate noise when current flows through them; crystal mixers; and electron tubes. Electron tubes generate noise because of random variations in electron emission from the cathode, random variations in current division between plate and screen, etc. In general, the more grids a tube has the more noise it generates.

The term, NOISE FIGURE (NF), indicates the amount of noise that is to be expected for a given receiver. It is the ratio of measured noise to calculated noise and may be expressed as a power ratio or in decibels. There are, however, variations in the way the noise figure may be expressed.

The three main sources of noise in a radar receiver are: first, the crystal mixer; second, the i-f preamplifier; and third, the local oscillator.

If the noise in a certain radar receiver becomes too high, something must be done to reduce it. First of all, another crystal mixer is substituted; in practice, several may be used

in turn and the one with the lowest noise chosen. The same precedure is used for the i-f preamplifier tubes. If the noise is still high, the local oscillator tube is replaced. It should be noted that the noise of a reflex klystron is much greater than normal when the tube is tuned off the center of a mode (a proper operating frequency).

The noise figures of early radars were in excess of 20 db, but modern receivers have noise figures between 6 and 18 db.

The noise figure of a radar receiver may be determined by the use of a noise generator or a c-w signal generator. The noise-generator method is more accurate.

A practical example will illustrate how a noise generator may be used to determine the noise figure of a radar receiver. The following are the steps that are involved in making the measurement:

1. A 0-1 milliammeter is connected in series with the diode load resistor of the second detector.
2. The receiver input is grounded, and the receiver gain control adjusted to produce a 0.5-ma reading. This reading is due to the internal noise alone.
3. The input ground is removed and the noise generator connected to the input of the receiver.
4. The output of the noise generator is adjusted until the meter reads 0.707 ma—that is (1.4 X 0.5 ma). The receiver gain control is NOT adjusted after the initial adjustment in step (2).
5. If in step (4) a further increase in noise input does not cause a corresponding increase in meter reading, the receiver is limiting and the readings will not be accurate. The procedure is to start with step (2) again and to reduce the receiver gain-control setting until the meter reads less than 0.5 ma. For example, reduce the reading to 0.3 ma. In step (4) the output of the noise generator should be adjusted to make the meter read 0.42 ma—that is (1.4 X 0.3 ma).
6. The noise-generator power output is now equal to the receiver noise power. This may be understood from the following. The resistance of the diode load resistor remains constant, and therefore the power dissipated in it varies as the square of the current, as read on the meter.

A simple analogy is shown in figure 6-21. As may be seen in the figure, when the current increases from 0.5 ma to 0.707 ma, the power is doubled. When the output of the noise generator is added to the receiver noise, and the output across the 1M resistor is doubled, the output of the noise generator is equal to that developed by the receiver noise. A chart is usually furnished with the instrument for converting the dial reading to power for various load resistances.

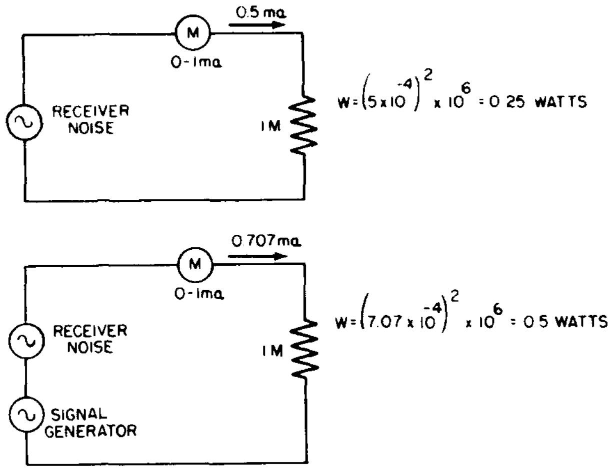

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Figure 6-21.—Simple power analogy.

7. The noise figure (NF) is determined as follows:

$$NF\ (db) = 10 \log \frac{\text{power measured}}{\text{power calculated}} .$$

Noise energy (calculated) has already been given as

$$NP = 4\ KT\ \Delta f.$$

Assume that the temperature is 20°C and that the receiver bandwidth is 4×10^6 cycles ($f_2 - f_1$).

$$\begin{aligned} NP &= 4(1.37 \times 10^{-28}) \times (20 + 273) \times (4 \times 10^6) \\ &= 6422.56 \times 10^{-17} \\ &= 0.06423\ \mu\mu W. \end{aligned}$$

Assume that the measured noise power of the receiver is $1.018\,\mu\mu W$. The noise figure in db is then

$$\begin{aligned} NF\ (db) &= 10 \log \frac{1.018}{0.0642} \\ &= 10 \log 15.86 \\ &= 10 \times 1.2 \\ &= 12\ db. \end{aligned}$$

Overall radar system sensitivity measurements are included in the following chapter under the treatment of the echo box.

RADIO.—The one measurement that provides maximum information about receiver condition in field operation is that of sensitivity.

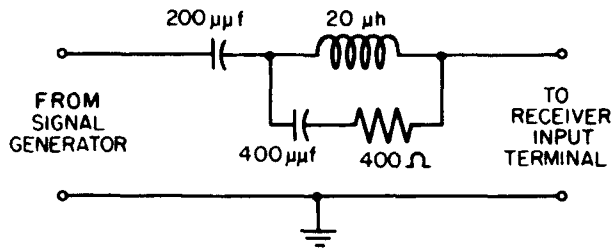
The sensitivity of a radio receiver is an indication of its ability to give a satisfactory output with a weak signal input. Although there may be some variation in the exact wording of the definition, sensitivity is the value of input carrier voltage that must be fed from the signal generator to the receiver input to develop a specified output power. The settings of the various controls are specified as well as the modulation frequency and percentage of modulation.

In many Navy receivers, sensitivity is the magnitude of signal voltage (in microvolts) that must be fed to the receiver antenna terminals in order to produce a standard output of 6 mw across a 600-ohm noninductive resistance substituted for the headphones or other device at the receiver output terminals. A signal-to-noise ratio of 10:1 is maintained for this test.

This measurement ordinarily requires the application of a calibrated input signal voltage to the antenna terminals of the receiver through an impedance, which approximates that of the antenna with which the receiver is to be used. This impedance is usually known as a DUMMY antenna. The dummy antenna ensures that the signal current in the input circuit of the receiver is the same as would appear with the calibrated signal voltage induced in an ideal receiving antenna. It also ensures that the input circuit of the receiver is "loaded" the same as it would be by an ideal antenna.

A dummy antenna that may be used with high-impedance input receivers is shown in figure 6-22. In the case of low-impedance input receivers of 50 to 70 ohms nominal impedance, a signal generator with a 50-ohm output, may be directly connected without the use of an external dummy antenna. Other generator impedances may require special dummy-antenna networks to load the generator and the receiver properly.

For sensitivity measurements, the receiver is adjusted for the type of reception desired. Controls, such as AGC, silencer, noise limiter, etc, are set according to the instructions in the instruction book. The power-line voltage and frequency applied to the receiver should be within the recommended operating range. The



1.65

Figure 6-22.—Dummy antenna circuit.

receiver output terminals should be properly loaded by substituting for the headphone or audio-line termination a 600-ohm noninductive resistor capable of dissipating the maximum output power (approximately 6 mw for this test).

High-impedance headphones may be used in shunt with the load for monitoring the output. Low-impedance headphones would load the output appreciably. The output voltage is measured with a high-impedance audio voltmeter capable of accurate indication from 0.1 v to 100 v. Although some receivers are equipped with audio output meters, their meters may not indicate the required standard noise levels with sufficient accuracy.

Detailed instructions for making sensitivity measurements are included in the instruction book that accompanies a particular receiving equipment. In some of these instruction books detailed information for making sensitivity checks for the various sections of the receiver are given. In other instruction books instructions for making sensitivity tests are included in receiver final testing.

A general idea of one method of making sensitivity measurements on c-w and facsimile receivers may be obtained from the following considerations. The test setup is shown in figure 6-23.

In part A, no signal is applied (input grounded), and the r-f gain control is adjusted to produce 60 μw (0.06 mw) of noise at the output—that is, 0.19 v across 600 ohms. This is the power developed by the noise. No further adjustment of the gain controls (either r-f or a-f) is made during the remainder of the test.

If a db meter is used to obtain this indication of noise level, the meter reading will be in decibels. For example, if the total resistance of the load is 600 ohms, and zero db is equivalent to 1 db (1 mw in 600 ohms), the indication of

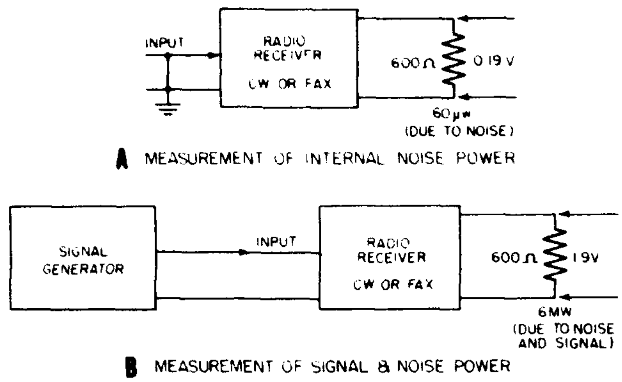


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Figure 6-23.—One method of making radio receiver sensitivity measurements.

the output meter will be $10 \log \frac{0.06 \times 10^{-3}}{1 \times 10^{-3}}$, or -12.2 db.

In part B, the unmodulated carrier signal is applied. The c-w oscillator frequency (receiver BFO) control is adjusted to produce a 1000 cps beat note. The input signal voltage to the receiver from the signal generator is then adjusted to produce an output of 6 mw. The value of voltage across 600 ohms required to produce this output may be calculated as follows:

$$E = \sqrt{PR}$$
$$= \sqrt{0.006 \times 600}$$
$$= 1.9 \text{ V}$$

If the same db meter is used to obtain this indication, the signal generator output is adjusted so that the meter reading will be

$10 \log \frac{6 \times 10^{-3}}{1 \times 10^{-3}}$, or 7.78 db.

The output signal-to-noise ratio (actually the signal-plus-noise to noise ratio), using the output voltages, is

$$\text{signal-to-noise ratio} = \frac{1.9 \text{ volts}}{0.19 \text{ volts}} = 10,$$

or a 10: 1 ratio; the power ratio is 100:1. The signal-to-noise ratio in db in terms of the power ratio is

$$\text{db} = 10 \log \frac{6 \times 10^{-3}}{60 \times 10^{-6}} = 20 \text{ db.}$$

The receiver sensitivity, in terms of input signal voltage in microvolts, is obtained from the signal-generator voltage calibration chart. For the example being considered, the input signal voltage is approximately 5 μv. Thus, the receiver sensitivity is expressed as 5 μv input to produce an output of 6 mw when the signal-to-noise ratio is 10 to 1. The correct sensitivity will appear in the Performance Standards Book for the receiver as a part of the data provided with the receiver.

MEASUREMENTS IN TRANSISTOR CIRCUITS

The many types of transistor base connection arrangements (discussed later in this training course) require that the leads be properly identified to secure correct hookup to the tester. The TS-1100/U test socket arrangement is compatible with some transistor types, but not all types. If the leads are long enough, it is generally possible to effect proper hookup by bending them. If the leads are too short, it will be necessary to use the test cable and alligator clips provided with the tester. In all cases, however, the transistor leads should be identified and then matched up with the tester connections.

The great advantage of the TS-1100/U lies not only in its accuracy and simplicity, but also in its use of a-c as the testing current. This eliminates interference from any d-c currents and voltages that may be present and permits measurement of the gain of a transistor in-circuit, thus making it unnecessary to unsolder or disconnect the transistor for this test. This is particularly advantageous where the transistor is mounted on a module printed wiring board.

The a-c testing current is provided by means of a built-in oscillator and amplifier. To avoid possible interference from other frequencies, the amplifier is sharply peaked for a single frequency, 2250 cycles per second. The test current is then rectified and read on a microammeter which has a full-scale deflection of 50 microamperes. The test is also provided with a variable bias supply. The method of determining beta for a given transistor is shown in figure 6-24. When the proper adjustments are made according to the instructions in the instruction book, the value of beta will be indicated directly on the meter.

TS-1100/U is also designed to measure collector leakage current, I_{CO}, which is read directly on the meter. The circuit arrangement

is shown in figure 6-25. The technical manual for the test set provides information concerning the collector bias to be applied for a particular transistor and the maximum permissible collector leakage current.

However, since this current is d-c, the reading may be affected by other d-c potentials in

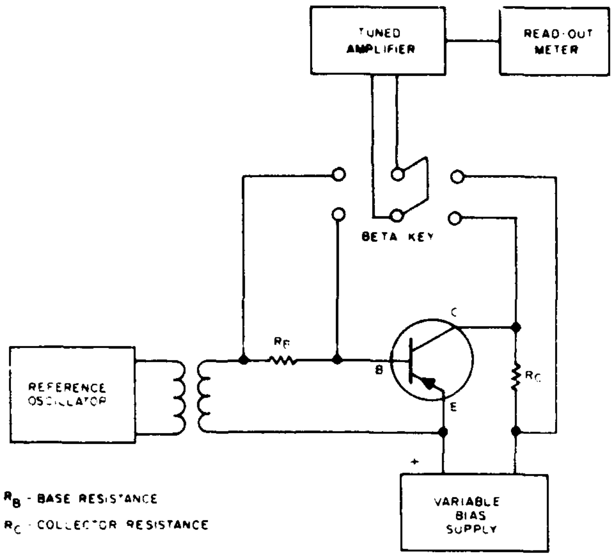

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Figure 6-24.—Measuring beta, using Transistor Test Set TS-1100/U.

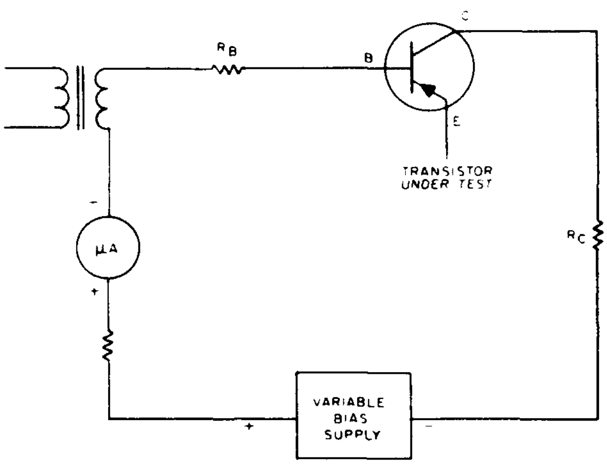

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Figure 6-25.—Measuring collector leakage current, I_{CO}, using Transistor Test Set TS-1100/U.

the circuit. For this reason it is necessary to remove the transistor from the circuit in order to obtain an accurate measurement of collector leakage current.

The test set is also equipped to indicate a short between any two of the three elements of the transistor under test. With the transistor in-circuit, it will also indicate a short if the circuitry between any two of the transistor elements has a resistance of 500 ohms or less. To determine whether the short is in the transistor itself or in the associated circuit, it is necessary to remove the transistor from the circuit.

The test set has the following additional features: a switch marked PNP-NPN, which selects the proper bias polarity for the type of transistor under test; a temperature alarm indicator lamp, which will light when the ambient temperature surrounding the equipment exceeds 50°C; and a switch marked TEST, which checks the test set battery output.

In conjunction with the transistor test set, multimeters, when used for voltage measurements should have a sensitivity of 20,000 ohms per volt or better on all voltage ranges. Meters with a lower sensitivity will draw too much current from the circuit under test when used in their low-voltage ranges. A VOM (20,000 ohms-per-volt) or an electronic voltmeter (VTVM) with an input resistance of 11 megohms or higher on all voltage ranges is preferred. However, a VTVM should be used with an isolating transformer between the VTVM and the power line.

Ohmmeter circuits which pass a current of more than 1 milliampere through the circuit under test cannot be used safely in testing transistor circuits. Many electronic voltmeters have ohmmeter circuits which exceed this safe value of 1 milliampere. High-sensitivity multimeters often are shunted on ohmmeter ranges, so that they also pass a current of more than 1 ma through the circuit under test. Before using any ohmmeter on a transistor circuit, the circuit it passes under test should be checked on all ranges. Do not use any range which passes more than 1 ma. To check the current, adjust the ohmmeter for resistance measurements; then connect a milliammeter in series with the test leads (fig. 6-26), and observe the indication on the milliammeter. The meter used should have a low resistance such as contained in Multimeter TS-352A/U or equivalent.

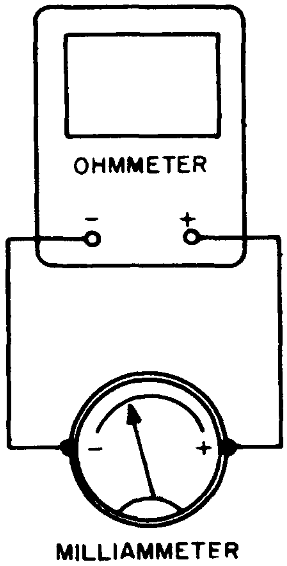

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Figure 6-26.—Measuring current passed by ohmmeter.

CHAPTER 7

USE OF TEST EQUIPMENT

The purpose of this chapter is to acquaint the technician with the practical use of test equipment. The operation and function of several of the most common test equipments used are included. The basic operating principles of the cathode-ray oscilloscope and the echo box are stressed.

A knowledge of the proper use of these instruments is one of the most valuable tools that an ET can have. The technician will find additional helpful information in the Handbook of Test Methods and Practices (latest edition), NavShips 91828, and in the instruction books that accompany the test instruments.

OSCILLOSCOPE OS-8B/U

The cathode-ray oscilloscope is generally used to permit the technician to observe voltage waveforms in testing electronic circuits. Because voltage waveforms are observed, an ELECTROSTATIC cathode-ray tube (CRT), which employs voltage to deflect the electron beam, is used.

Some oscilloscopes may use an ELECTROMAGNETIC CRT, which employs current to deflect the electron beam. This type of oscilloscope is used for certain applications, other than general testing, where its properties make it more suitable than the electrostatic-deflection type.

In general, test oscilloscopes are used to align and test electronic equipment, to make hum measurements, to make frequency comparisons (to determine an unknown frequency), to observe complex waveforms, and to make modulation percentage measurements.

The OS-8/U series of oscilloscopes supersedes older Navy models. Improvements are also being made in the OS-8/U series. For example, the OS-8A/U has a better square-wave response than the OS-8/U, although it is slightly heavier and larger.

A simplified block diagram of the OS-8B/U oscilloscope is shown in figure 7-1; a view of the controls are shown in figure 7-2.

The VERTICAL ATTENUATOR determines the fraction of the a-c input voltage that is to be applied to the vertical amplifier via the cathode follower. The a-c input to the vertical amplifier may not be reduced at all (vertical attenuator in the 1:1 position), or it may be reduced 10:1 or 100:1, depending on the position of the vertical attenuator switch. The purpose of this arrangement is to avoid overloading the vertical deflection amplifier of the oscilloscope.

The cathode follower provides a high-input impedance and a low-output impedance, at which point the vertical Y GAIN control is inserted. The high-input impedance prevents excessive loading of the circuit under test. Inserting the gain control at the low-output impedance point avoids frequency discrimination caused by circuit distributed capacitances.

The vertical amplifiers boost the amplitude of the applied signal so that the desired vertical displacement may be obtained on the screen of the CRT. When the SYNC SELECTOR switch is in the INTERNAL position, a portion of the vertical output voltage is used to synchronize the horizontal sweep.

The horizontal amplifiers amplify the saw-tooth signal that is to be applied to the horizontal deflection plates. The length of the horizontal sweep line, as it appears on the CRT screen, is determined by the setting of the horizontal X GAIN control.

The Sync Selector switch determines the source of the synchronizing voltage. The source may be the signal applied to the vertical plates, the line voltage, or the signal applied to the external sync terminal.

The sweep generator generates a linear voltage waveform (saw-tooth waveform), which, when applied to the horizontal deflection plates

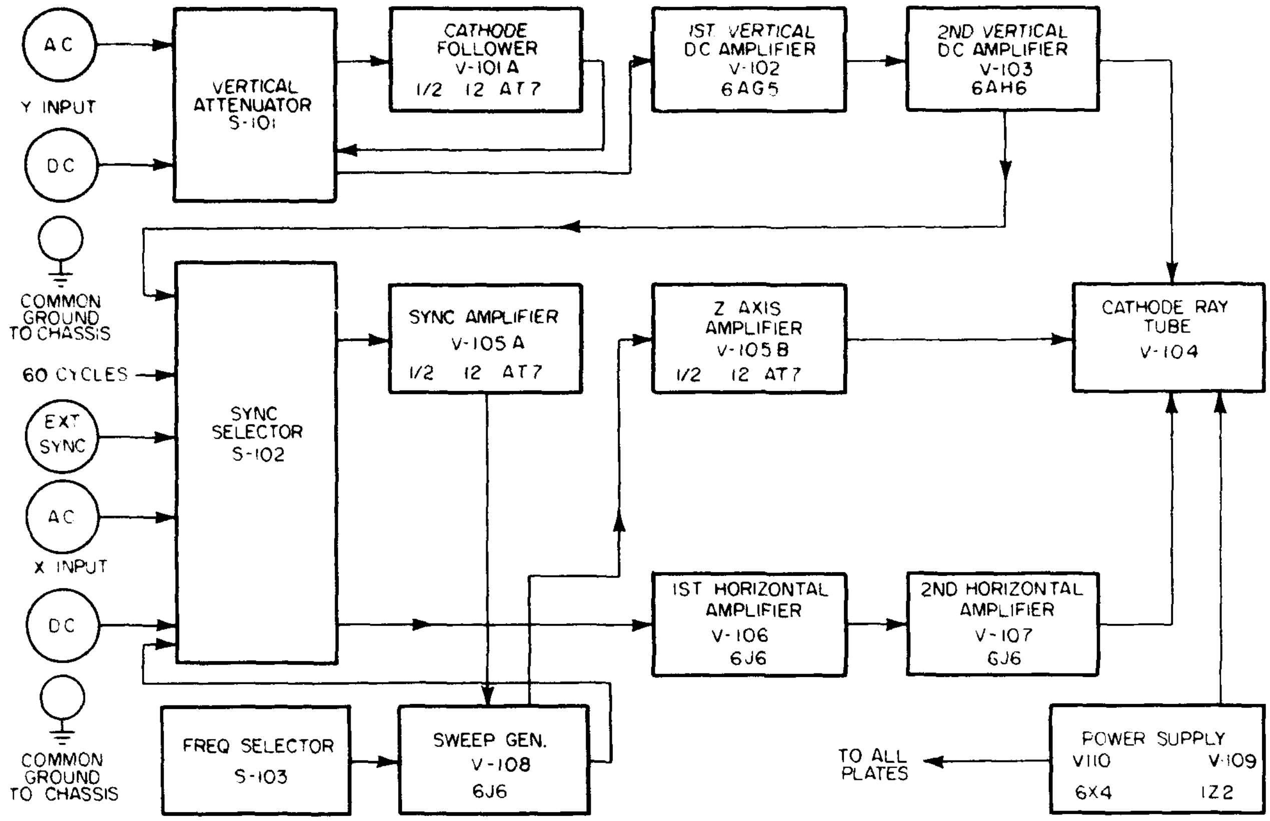

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Figure 7-1.—Simplified block diagram of the OS-8B/U oscilloscope.

of the CRT, results in a trace that progresses across the screen from left to right at a constant rate of speed. The frequency of the internally generated sweep is determined by the setting of the SWEEP RANGE switch and the SWEEP VERNIER.

The sync amplifier amplifies the sync signal and feeds it to the sweep generator.

The Z axis (blanking) amplifier and its associated circuit control the variation of the intensity of the trace throughout the sweep cycle. A jumper is normally connected across the blanking terminals of the terminal board at the CRT in order to blank the sweep return trace. If desired, the jumper may be removed and an external voltage introduced across the terminals to intensity modulate the trace throughout the cycle.

The INTENSITY control decreases or increases the bias on the grid of the CRT so that the number of electrons allowed to pass through the control grid is regulated. This control also turns off the power supply when rotated to its extreme counter-clockwise position.

The FOCUS control changes the voltage on the focusing electrode of the CRT and thus permits the sharpening of the trace on the screen.

The Y POSITION control moves the beam or trace up or down on the face of the tube; the X POSITION control moves the beam or trace horizontally on the face of the tube. By means of these controls, the trace may be positioned at any place on the screen.

The SYNC AMPLITUDE control varies the strength of the signal applied to the sweep generator. It may be set so that the sweep generator will be synchronized on either positive or negative signals.

The SWEEP RANGE control is a coarse setting for the sweep frequency desired; the

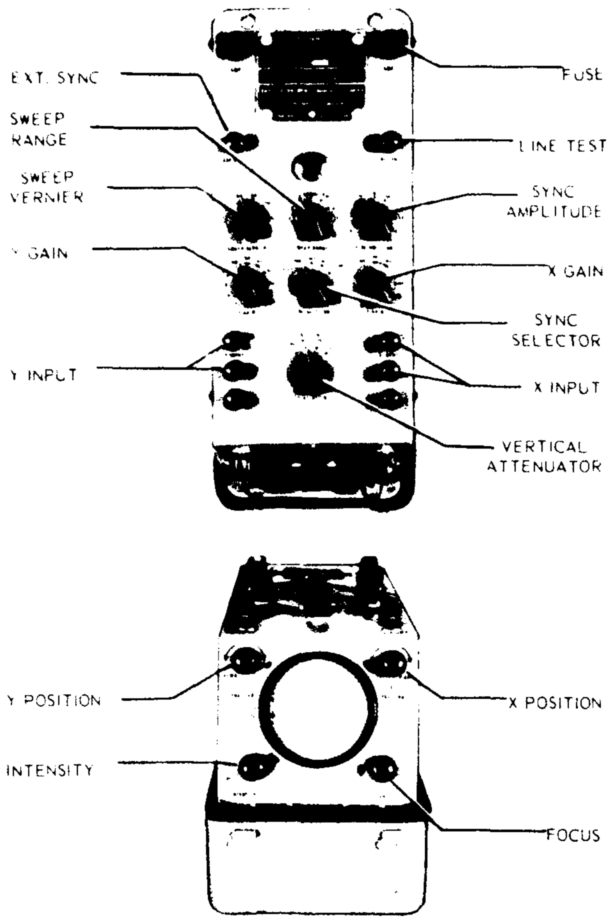

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Figure 7-2.—Oscilloscope OS-8B/U controls.

sweep vernier is a fine setting for the same signal and is continuously variable within the limits set by the sweep range.

The sync selector permits different sync sources to be applied to the sync amplifier. In the EXTERNAL position, the sweep is synchronized with the voltage source connected to the external sync terminal. In the LINE position, the sweep is synchronized with the power-supply frequency; and in the INTERNAL position, the sweep is synchronized with the signal being applied to the Y INPUT. In each of these three positions the sync signal is under the control of the sync amplitude potentiometer. When the sync selector is in the A-C or D-C position, the sweep generator is cut out of the circuit, and the horizontal deflection is controlled entirely by the voltage connected to the X-INPUT terminals. A capacitor is connected in series with the a-c terminal, and the response is limited at the low-frequency end to approximately 25 cycles per second. When the d-c terminal is used, the deflection will respond to low frequencies as well as to direct current.

The Y gain controls the amplitude of the vertical amplifier output, and the X gain controls the amplitude of the horizontal amplifier output.

The Vertical Attenuator determines the fraction of the a-c input voltage that is applied to the vertical amplifier. Thus, in the 1:1 position, no reduction takes place; in the 10:1 position, the voltage is reduced to one-tenth; in the 100:1 position, the voltage is reduced to one-hundredth. In the d-c position, the attenuator and the cathode follower are bypassed. In this position, low frequencies (up to 1000 cycles) may be connected between the d-c input terminal and ground with essentially no resulting distortion.

The exact method of operating the controls is given in the instruction book that accompanies the equipment.

GENERAL INFORMATION

To obtain an accurate presentation of the voltage waveform, a few precautions must be observed. The approximate magnitude of the voltages in the circuit under test must be known so that the operator can take steps to safeguard himself from shock and the oscilloscope from a voltage breakdown.

Dependable data can be obtained from the oscilloscope only if its sensitivity and frequency characteristics are known. To make certain that the waveform will not be distorted it is essential that the manner in which distortion takes place be understood and that precautions be taken to minimize such distortion.

INPUT CIRCUIT.—The input to most oscilloscopes is between an input terminal (which is above ground potential) and the common ground terminal. The input terminal is almost always coupled to the grid of the amplifier through a capacitor. Seldom do the capacitors used have voltage ratings in excess of 450 volts. Therefore, unless the approximate magnitude of the voltage under test is known, damage to the oscilloscope through breakdown of the input capacitor may result.

VOLTAGE DIVIDERS.—In some cases, it may be necessary to observe waveforms in circuits where the voltage is much greater than the components within the oscilloscope can withstand. A voltage divider may be used in such instances to reduce the voltage to a value that will not damage the equipment. In any case, it is very important that the oscilloscope be adequately grounded. Grounding the oscilloscope is a precaution that must be taken for the protection of the operator, because a failure of some part of the voltage divider can raise the potential of the whole oscilloscope to a dangerous level if the oscilloscope case is not solidly connected to ground.

If the voltage divider used is a capacitance divider, a wise precaution is to shunt each capacitor with a high resistance in order to maintain the proper voltage distribution across each capacitor. Two voltage dividers are shown in figure 7-3. In Part A, the capacitance alone causes the voltage across C2 to be one-tenth of the voltage across C1. However, the leakage resistances, R1 and R2, may be of such values that they divide the voltage by a very different ratio. If the leakage resistance of the capacitors is high with respect to the magnitude of the X_C ohms, the leakage resistance will have negligible effect on the voltage distribution across the capacitors. However, if the leakage resistance is of the same order of magnitude as that of the X_C ohms, the leakage resistance may have a pronounced effect on the distribution of the voltage across the capacitors. This condition might cause excessive voltage across one capacitor and result in a breakdown. To prevent this unbalanced distribution of voltage, resistors R3 and R4 may be added, as in figure 7-3, B. Because the leakage resistance of a good capacitor is of the order of 1000 megohms and because R3 and R4 are relatively low in resistance, the two resistors fix the voltage division at the same ratio as do the capacitors, and the voltage divider may be easily designed to withstand the high voltage.

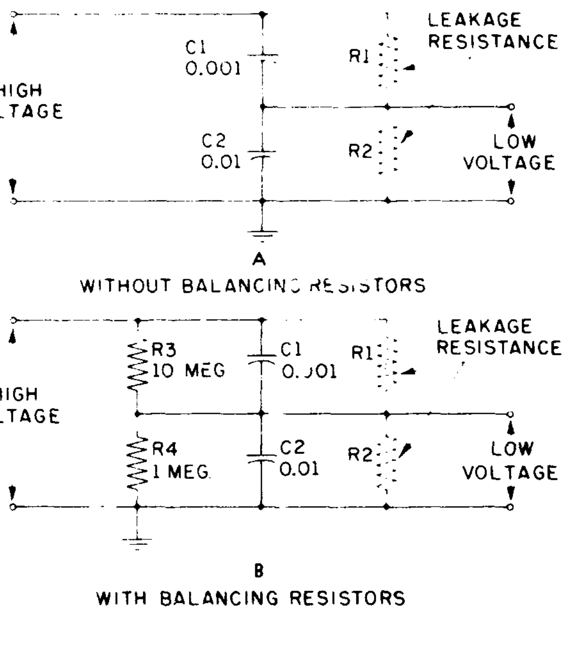

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Figure 7-3.—Capacitance voltage divider.

FREQUENCY RANGES.—The range of sweep frequencies in a given oscilloscope is usually indicated on the front panel of the instrument. The frequency range that the vertical and horizontal amplifiers are capable of amplifying properly is given in the manufacturer's instruction book. Generally, only the best oscilloscopes use amplifiers that will amplify voltages whose frequency is below 20 or above 1,000,000 cycles per second. Oscilloscopes that do not cover as wide a range of frequencies as this may be satisfactory for most uses, but distortion is likely to occur when saw-tooth or rectangular waveforms of a high recurrence rate are investigated. High performance oscilloscopes are capable of amplifying over a broader frequency range, and, accordingly, may be used on rectangular and saw-tooth waveforms of high recurrence rates without distorting the shape of the waveform.

DEFLECTION SENSITIVITY.—The deflection sensitivity of an oscilloscope may be defined as the distance in millimeters that the spot is moved on the screen when 1 volt is applied to the deflecting plates. The deflection sensitivity in this case is expressed in millimeters per volt. The most accurate way of measuring this quantity is to apply a known d-c potential directly to the deflecting plates and measure the distance that the spot is moved by this voltage. The number of millimeters that the spot moves, divided by the voltage applied, is the deflection sensitivity in millimeters per volt.

The deflection sensitivity (or factor) may also be expressed as the input voltage to the

amplifier (horizontal or vertical) for a deflection of 1 inch of the spot on the CRT screen. In this case, the amplifier gain control is adjusted to a suitable value that is arbitrary (for example, midscale). The magnitude of the input sine-wave voltage is measured with an accurate a-c voltmeter. Most a-c voltmeters indicate the root-mean-square (rms) value of voltage. However, the deflection of the spot on the screen is proportional to the amplitude of the sine wave from the positive peak to the negative peak (peak-to-peak voltage). To convert the rms voltage at the input to peak-to-peak voltage, the input meter reading must be multiplied by 2.828.

Thus, the effective sensitivity (gain) of the oscilloscope in volts per inch is the peak-to-peak voltage applied at the input of the amplifier divided by the peak-to-peak amplitude of the trace in inches. For example, if the peak-to-peak voltage applied to the vertical amplifier is 2.8 millivolts and the peak-to-peak amplitude of the trace is 2.8 inches, the vertical deflection sensitivity will be $\frac{0.0028}{2.8} = 0.0001$ volt per inch. If the gain control is changed, the effective sensitivity will also change. However, the sensitivity of the CRT itself is not affected by the use of the amplifier. The only factor changed, when changing the gain control, is the amplitude of the voltage applied to the deflecting plates.

If the peak-to-peak voltage applied directly to the vertical deflection plates without going through the amplifier is 48 volts and the peak-to-peak amplitude of the trace is 1 inch, the vertical direct deflection sensitivity will be 48 volts per inch.

STRAY PICKUP.—To avoid pickup of stray signals, the leads from the circuit under test to the oscilloscope should be as short as possible. If the leads are long, a greater voltage can be induced in them by stray fields than would be induced if the leads were short. The pickup may be so disturbing in some cases that it will be almost impossible to use the oscilloscope. A few things can be done to reduce the effect that stray fields have on the oscilloscope.

First, the cathode-ray tube must be very carefully shielded from all stray fields. In most cases, this shielding is provided by the Aquadag coating on the inside of the tube, by a metallic shield outside the tube, and by the oscilloscope case.

Second, the common side of the oscilloscope circuit should be connected to a ground point in the circuit under test and to a good external ground connection. This connection will aid in eliminating most of the stray voltages that are picked up by the leads.

Third, a low-capacitance coaxial cable may be used to reduce still more the effect of stray fields.

DISTORTION.—Several sources of distortion are possible in the production of CRT display. Although distortion can be eliminated by simple precautions in some cases, it is very difficult to eliminate in other cases. A summary of some of the major factors to be considered follows.

1. Perhaps the most obvious component in which distortion can enter is the deflection amplifier. It is important, therefore, to know the frequency response of the amplifier being used. An estimate may then be made of the possibility of distortion for a given signal.

2. If the sweep is nonlinear, the shape of the wave on the screen will not be a true picture of the voltage under test. However, if the oscilloscope is not defective, the sweep will generally be linear enough for most purposes.

3. When signals of relatively high frequency are to be observed, the time of fly-back may become an appreciable fraction of the period of the signal. To avoid distortion of this type, it is well to adjust the sweep frequency so that several cycles of the signal will appear on the screen.

4. If the magnitude of the synchronizing voltage is too great, the image may be distorted because the sweep is terminated too soon. This condition may be avoided by setting the synchronization control at zero while the sweep frequency is adjusted. When the sweep frequency is some integral multiple of the signal frequency, the image will be stationary on the screen. The synchronizing voltage should then be turned up just enough to stop the apparent motion of the image on the screen.

5. In general, the input impedance of the oscilloscope will be much higher than the impedance of the circuit at the point where the test is to be made. Therefore, the input impedance of the oscilloscope will not change appreciably the circuit load nor the voltage

at the connection point, and a true picture of the voltage may be observed. In some circuits, however, the impedance may be very high (perhaps up to 100 megohms), and the input impedance of the oscilloscope may load the circuit and change the voltage so radically that it will be difficult to obtain a true picture.

6. The input shunting capacitance of an oscilloscope is generally small (of the order of 20 to 60 $\mu\mu f$), but it may be sufficient to alter the characteristics of a video amplifier or the tuning of a high-frequency oscillator.

7. When one specific type of equipment is to be maintained, many of the preceding sources of distortion may become of academic interest only. When, for example, the same oscilloscope is used with the same pair of leads to check repeatedly a given set of waveforms, the distortion will always be the same if the circuits are operating properly. If the waveforms through the system are recorded when the system is working properly, the maintenance testing need consist only of a comparison of the waveforms obtained with the recorded standard waveforms. In such a case, it is not necessary to eliminate all distortion, because the test will consist of a comparison of two sets of data that are distorted in the same way. It is desirable, however, to eliminate distortion as much as possible in order that the operation of the circuit under test may be better understood. However, successful testing may be performed regardless of distortion, if the same test equipment is used in the same way in every check.

Signal Tracing

SINE WAVEFORM.—The cathode-ray oscilloscope (CRO) is used chiefly for checking the waveform of the signal voltage in electronic circuits. The most commonly found waveform in a-c power circuits is the sine wave. Most cathode-ray oscilloscopes (for example, the OS-8B/U) have a line-test signal binding post internally connected to a low-voltage winding of the power-supply transformer so that an a-c voltage at power-line frequency (60 cycles) is available for testing purposes. A jumper may be connected between the line test signal binding post and the a-c Y input. If the sweep range is set on the line between 15 and 75 and the sweep vernier is adjusted to 60, a single cycle of sine waveform will appear on the cathode-ray screen. This pattern may be used for comparison with other sine waveforms.

OTHER WAVEFORMS.—Oscilloscope AN/USM-24 is an equipment for displaying a luminous plot of the time variation of a voltage pulse or wave, with self-contained means for measuring its duration and instantaneous magnitude. It is intended for use in testing all types of electronic equipment in the radar and communications fields. The waveforms may be square wave, saw-tooth, peaked, sinusoidal, or modifications of any or all of these.

In general, the method of obtaining the signal waveform is to adjust the horizontal sweep frequency to approximately the frequency of the signal voltage to be presented on the screen and then to apply the signal voltage to the Y input binding post, making sure that the ground terminal is returned to the ground on the equipment from which the test voltage is derived. The horizontal gain control is then adjusted for full horizontal deflection and the vertical gain control adjusted for slightly less than full scale deflection. If the pattern is not properly centered on the screen, the horizontal and vertical positioning controls should be adjusted until the desired centering is obtained.

The CRO is used in signal tracing to determine the location of a fault. The signal voltage is derived from various test points (for example, in the circuit shown in figure 7-4) and the pattern compared with the pattern for each particular check point, as indicated in the figure. The bandwidth and the sweep frequency of the test CRO are indicated for specified conditions of equipment operation. For example, at test point TP107, the sweep frequency (SF) of the test oscilloscope is designated as 60 cycles; the duration of the zero voltage condition is 15,000 μs (T), and the length of the negative-going pulse (-100 v) is 1670 μs (T). The letter, R, designates the range setting of the equipment.

As a Measuring Device

D-C VOLTMETER.—The electrostatic CRT is a voltage operated device. The amount of deflection of the spot is proportional to the magnitude of the voltage applied to the deflecting plates. If the deflection sensitivity of the CRT is known, the oscilloscope can be used as a voltmeter on either direct or alternating voltages. The oscilloscope has the advantage of

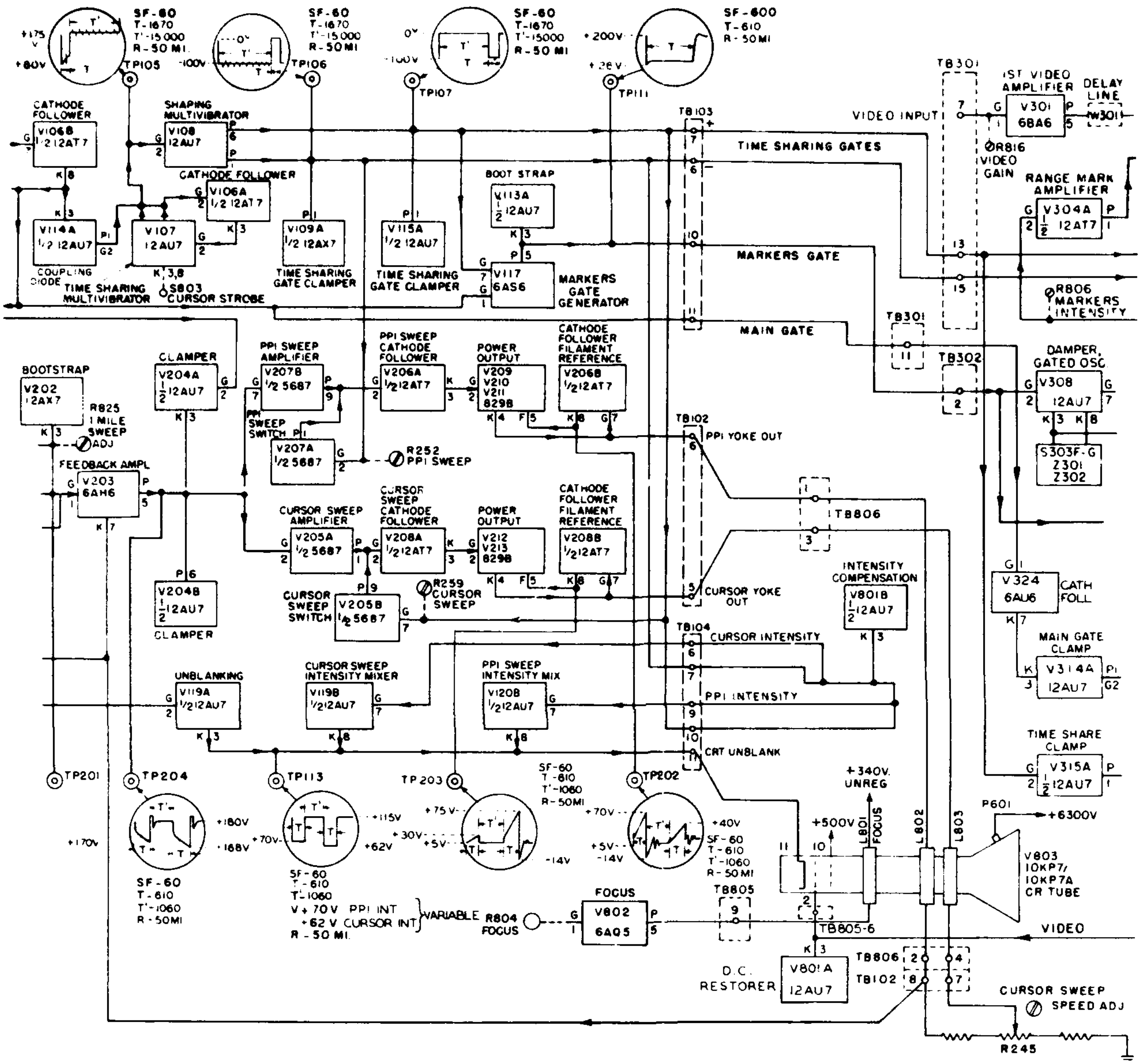

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Figure 7-4.—Signal tracking with the CRO.

having extremely high input impedance when the voltage to be measured is applied directly to the deflecting plates. However, because both the range of voltage measurements and the accuracy of indication are less than that available in commercial d-c voltmeters, the oscilloscope is not widely used for the measurement of d-c voltages.

A-C VOLTMETER.—The CRO is a better device for measuring alternating voltages than most conventional a-c voltmeters. The principal difficulty with the oscilloscope is the calibration of its deflection sensitivity. If this factor can be determined accurately, the magnitude of the alternating voltage can be determined very simply. The advantages of the oscilloscope as

an a-c voltmeter are its very high input impedance, its ability to measure equally well voltages of a wide frequency range, and its ability to indicate magnitude, regardless of waveform.

The oscilloscope shows the peak value of the applied a-c voltage; whereas, standard a-c meters show the rms values of the sine-wave, a-c voltage. Peak values may be readily converted to rms values, but the results may be misleading for voltages whose waveforms are other than sinusoidal.

AMMETER.—The electromagnetic CRT is a current operated device. Accordingly, it could be used to measure current magnitudes directly if it were properly calibrated. This type of tube, however, is rarely used in test oscilloscopes. The electrostatic CRT, as mentioned previously, is widely used in test oscilloscopes, and it may be used to measure currents indirectly. If the current to be measured is passed through a calibrated resistor, the resulting voltage across the resistor may be indicated on the oscilloscope screen. By application of Ohm's law, the current may be calculated; that is, R is known, E is measured, and I can be calculated by the equation,

$$I = \frac{E}{R}.$$

WATTMETER.—The same method that is used to measure current can also be employed to measure power. The power dissipated in a resistor is equal to the product of the current through the resistor and the voltage across it. Therefore, the power dissipated in the resistor may be expressed as

$$P = EI = \frac{E^2}{R}.$$

If the voltage measured by means of the oscilloscope is substituted in this equation, the power may be calculated (if the resistance is known).

Lissajous Figures

A Lissajous figure is a pattern created on an oscilloscope screen when sine-wave voltages (usually of differing frequencies) are applied simultaneously to both the horizontal and vertical deflecting plates. One of the principal uses of Lissajous figures is to determine an unknown frequency by comparing it with a known frequency.

DEVELOPMENT OF SIMPLE FIGURES.—The development of four types of Lissajous figures is shown in figure 7-5. Each Lissajous figure is developed by plotting a smooth curve through points formed by the intersection of horizontal and vertical lines projected from corresponding points on two sine curves (bottom and right side of Lissajous figures). Adjacent points on the sine curves at the right are separated by equal intervals (30°). Those on the sine curve at the bottom are separated by an interval of 15°. The ratio (horizontal to vertical) of the frequencies applied to the two pairs of deflecting plates is 1:2; that is, in this figure the frequency on the horizontal deflecting plates is one-half the frequency on the vertical deflecting plates. It does not matter what the actual frequencies are, as long as one of the frequencies is known.

If the two voltages are in phase; that is, if both voltages are passing through zero and going positive at the same instant, a figure eight pattern will be traced (fig. 7-5,A). As the phase changes slightly, the pattern will change, as shown in figure 7-5, B, C, and D. When the phase angle is 90°' the loops will colse, as in C. If the phase angle is greater than 180°, the pattern will be inverted, as in D.

INTERPRETATION OF PATTERNS.—One feature that all of these images have in common is that the pattern touches the horizontal lines (xx or x'x' of figure 7-5, A) at two points. This is true of the remaining patterns of the figure, even for the line tangent to the top of figure 7-5, C, because the trace passes point 1 on the figure twice during each cycle. Likewise, the vertical lines (yy or y'y') are touched by the pattern at only one point. The ratio of the number of points of tangency is equal to the ratio of the two frequencies. Expressed as and equation,

$$\frac{f_h}{f_v} = \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}}$$

where f_h is the frequency of the signal applied to the horizontal deflecting plates and f_v is the frequency of the signal applied to the vertical deflecting plates.

The number of tangent points on the horizontal and vertical lines is most easily counted when the Lissajous figure is stable (not moving) and when it is symmetrical. The ratio of the number of points of tangency on the vertical line to the number on the horizontal line is 1:2. If $f_v = 120$ cycles,

$$f_h = f_v \frac{\text{number of tangent points on vertical line}}{\text{number of tangent points on horizontal line}}$$
$$= 120 \times 1/2 = 60 \text{ cycles.}$$

MISCELLANEOUS FIGURES.—In figure 7-6, several varieties of Lissajous figures are shown. The ratio (horizontal to vertical) of the two input frequencies is indicated in each case. Unless the oscilloscope screen is very large, ratios higher than 10:1 are difficult to interpret. The circle shown in figure 7-6, A, is the simplest type of Lissajous figure. The pattern in figure 7-6, B is for a 2:1 ratio. Compare this with the pattern shown in figure 7-5, A, in which the ratio is 1:2.

Figure 7-6, C through F, indicates the increasing complexity that is encountered in ratios of higher order.

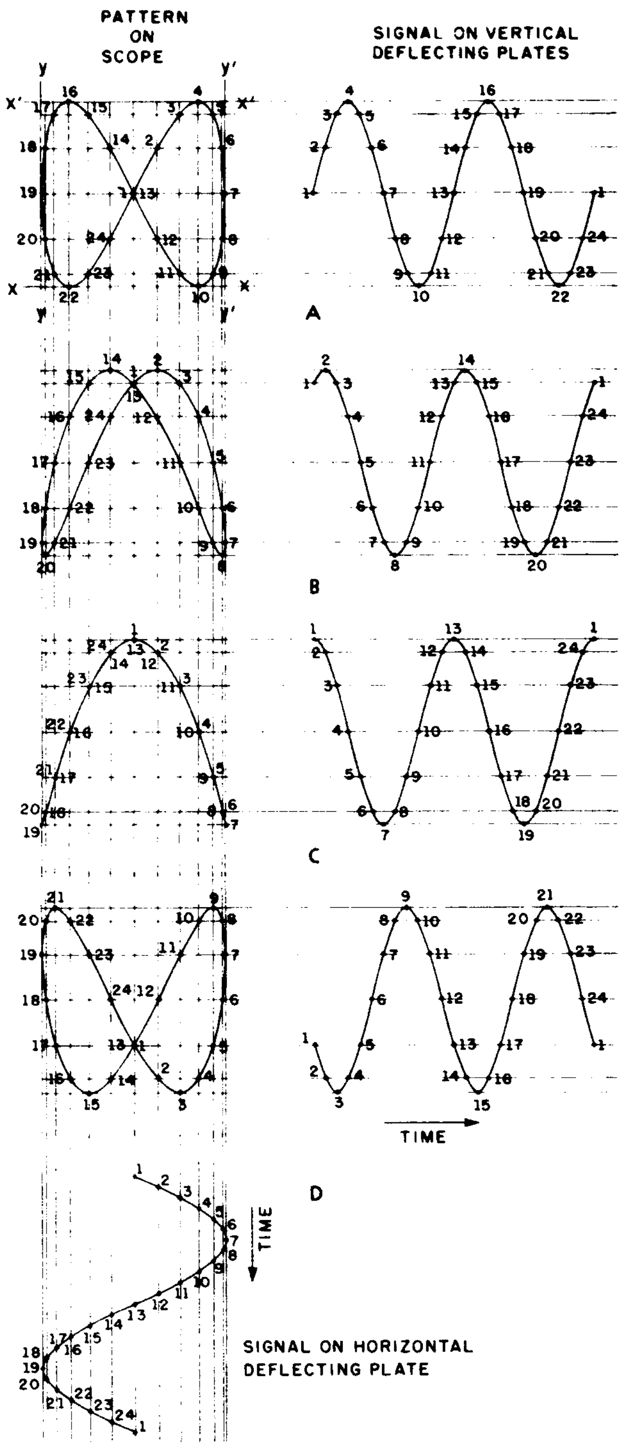

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Figure 7-5.—Lissajous figures for a 1:2 horizontal to vertical input frequency ratio.

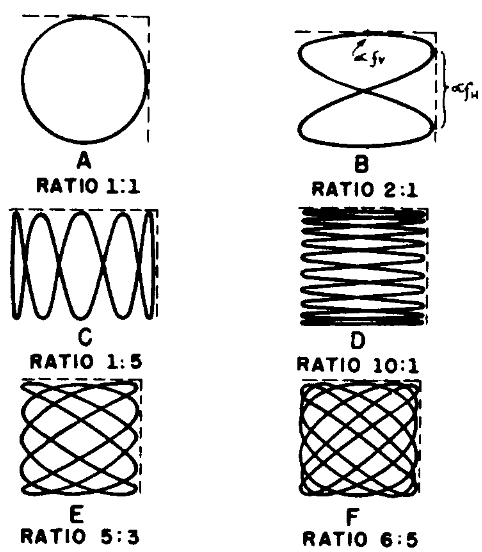

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Figure 7-6.—Lissajous figures for various frequency ratios.

INDICATION OF PHASE.—The patterns of figure 7-7 are formed by applying to the deflecting plates sine-wave voltages having the same frequency and amplitude, but having various phase differences. It can be seen in figure 7-7, A, that the resultant trace is a line at a 45° angle when the voltages are exactly in phase (0° or 360°). As the phase angle is made greater, the straight line opens into a broadening ellipse, as in figure 7-7, B and C. When the phase difference is 90°. the ellipse becomes a circle, as in figure 7-7, D. As the phase difference is increased beyond 90° (fig. 7-7, E through G), the circle begins to collapse toward another straight line, but this time the line is at 135° when the voltages are out of phase by 180°.

The patterns shown in figure 7-7 can be obtained only if the amplitude of the voltage applied to the vertical deflecting plates is the same as the amplitude of the voltage applied to the horizontal deflecting plates. If one voltage is greater than the other, the pattern will never become circular, but will always be elliptical. Therefore, if such patterns are to be used to measure the phase difference between two sine-wave voltages, care must be taken to ensure that both voltages are of the same amplitude, so that the screen can be calibrated.

Modulation Measurements

Amplitude modulation measurements are made by the observation of one of two basic modulation patterns—the wave-envelope or the trapezoidal pattern—either of which gives a continuous, direct picture of the modulated output of the transmitter.

The WAVE ENVELOPE pattern gives a direct indication of the shape of the modulation envelope, as indicated in figure 7-8, A. A small pickup loop is coupled inductively to the final tank circuit of the transmitter and connected directly to the vertical deflection plates. The CRO saw-tooth generator is used to provide the horizontal sweep frequency.

When an audio signal generator is used in place of the microphone voice input, a voltage of sine waveform is supplied to the modulator, and the pattern on the CRT is easily stabilized by applying a portion of the audio voltage to the external sync terminal of the oscilloscope. The audio voltage is obtained from the voltage divider composed of R1, R2, and C. Capacitor C blocks the d-c component and couples the

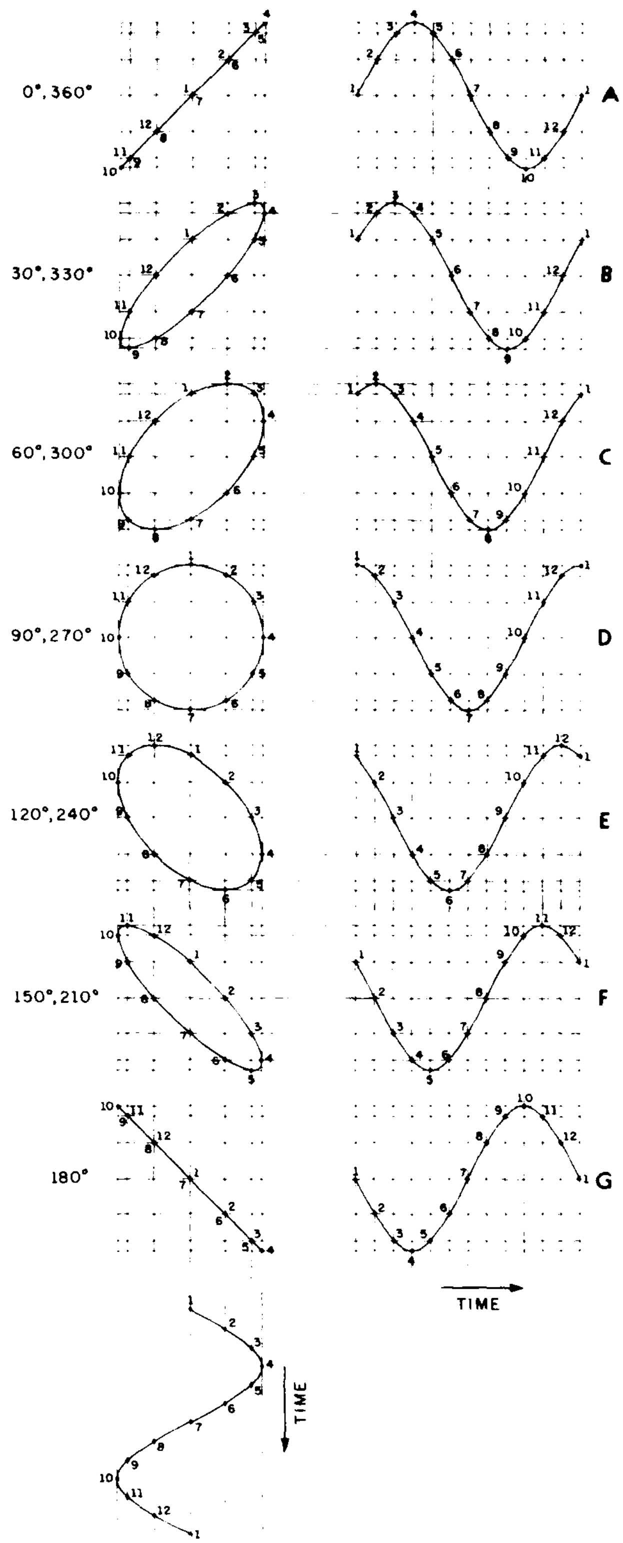

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Figure 7-7.—Lissajous figures that indicate phase difference.

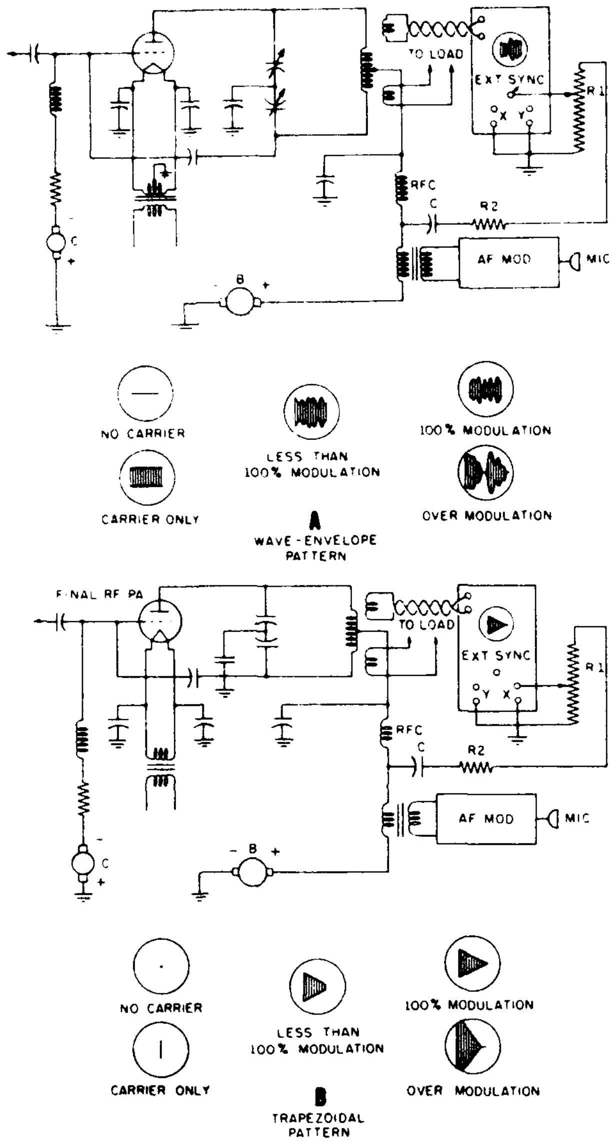

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Figure 7-8.—Modulation measurements.

a-f component to the sync input. The frequency-range vernier and sync-signal controls are adjusted until the audio component of the modulated wave is synchronized with the sweep, as indicated by a stationary pattern. When voice modulation is used, a rapidly changing pattern of varying height is obtained.

When the maximum height of the pattern is twice that of the unmodulated carrier, the carrier is modulated 100 percent. Several operating conditions are shown in figure 7-8, A. In order to determine the modulation percentage for any value below 100-percent modulation, the following procedure is followed:

The peak-to-peak height (H_2) of the unmodulated carrier is subtracted from the peak-to-peak height (H_1) of the modulated carrier, and the difference divided by the peak-to-peak height (H_2) of the unmodulated carrier. The result is then multiplied by 100 to give the percentage of modulation. As a formula,

$$\text{modulation percentage} = \frac{H_1 - H_2}{H_2} \times 100.$$

The TRAPEZOIDAL pattern is more difficult to obtain, but it gives more accurate information, particularly when nonsinusoidal waveforms are encountered. As indicated in figure 7-8, B, the vertical plates of the CRT are connected via the small pickup loop to the final tank circuit. The voltage divider, R1 and R2, across the modulation transformer secondary and the high voltage power supply provides the a-f voltage component that is applied to the horizontal input in lieu of the saw-tooth sweep frequency. Potentiometer R1 is varied until a satisfactory sweep is obtained on the screen of the CRT. The percentage of modulation is calculated in the same manner as that of the wave-envelope pattern.

THE SYNCHROSCOPE AN/USM-24

The synchroscope is a test instrument that has a wide range of applications because it includes the features of an oscilloscope plus such additional features as pulse synchronizing adaptations and markers that make it highly useful in radar testing or other testing where pulse analysis is necessary.

There are several synchroscopes available—for example, the TS-34/AP, AN/USM-32, TS-28/UPN, and AN/USM-24. Certain instruments that are, in fact, synchroscopes are sometimes designated as oscilloscopes.

A general idea of the operating characteristics of synchroscopes may be obtained from the following technical data.

For the model TS-28/UPN, the video amplifier has a frequency range of 1000 cycles to 5 megacycles.

Sweep for the oscilloscope can be internally triggered or it can be triggered by an external pulse or signal.

The internal trigger generator provides a self-generated internal triggering pulse to the apparatus under test and to the sweep and calibration mark circuits of the synchroscope when an external trigger source is not being used. The trigger frequency range is from 330 cycles to 4000 cycles.

Marker pips, synchronized with the sweep (whether internally or externally triggered), can be superimposed upon the trace of the CRT. These markers (having time ranges of 2, 10, or 25 microseconds between pips) can be used for measuring pulse width for determining pulse repetition rates, and for calibrating the sweep.

The synchroscope can also supply a synchronizing pulse of either positive or negative polarity for triggering radar or other equipment under test so that the trace appears stationary on the face of the CRT.

The following description of a representative synchroscope (oscilloscope AN/USM-24) will give the technician a general idea of the operating principles of this versatile piece of electronic test equipment. A front view of the instrument is shown in figure 7-9.

The instrument consists basically of nine channels, which are described in the following paragraphs. During the discussion, reference should be made to the block diagram of figure 7-10.

DISPLAY CHANNEL.—The heart of the display channel is the CRT. In general, the operation of the CRT is similar to those used in regular test oscilloscopes.

VERTICAL CHANNEL.—The function of the vertical channel is to transmit the signal from

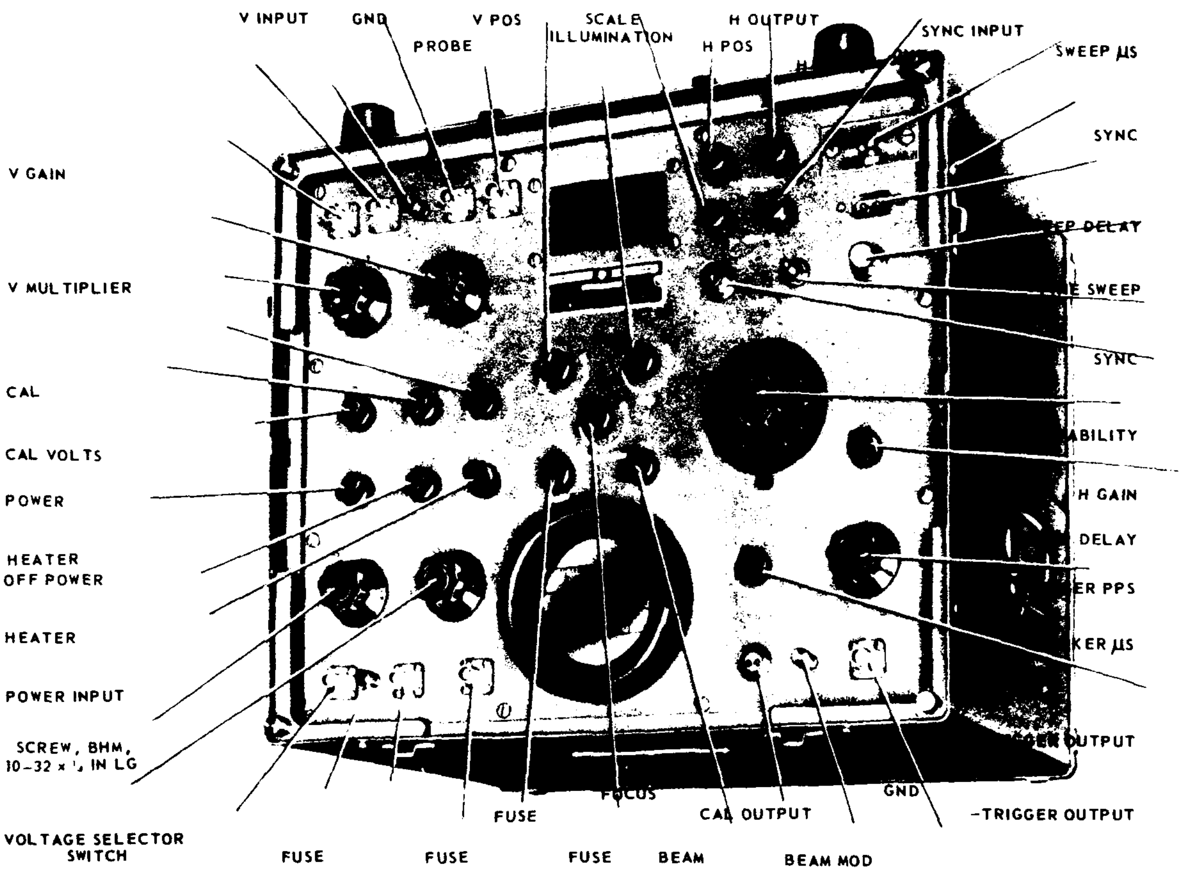

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Figure 7-9.—Front view of oscilloscope AN/USM-24.

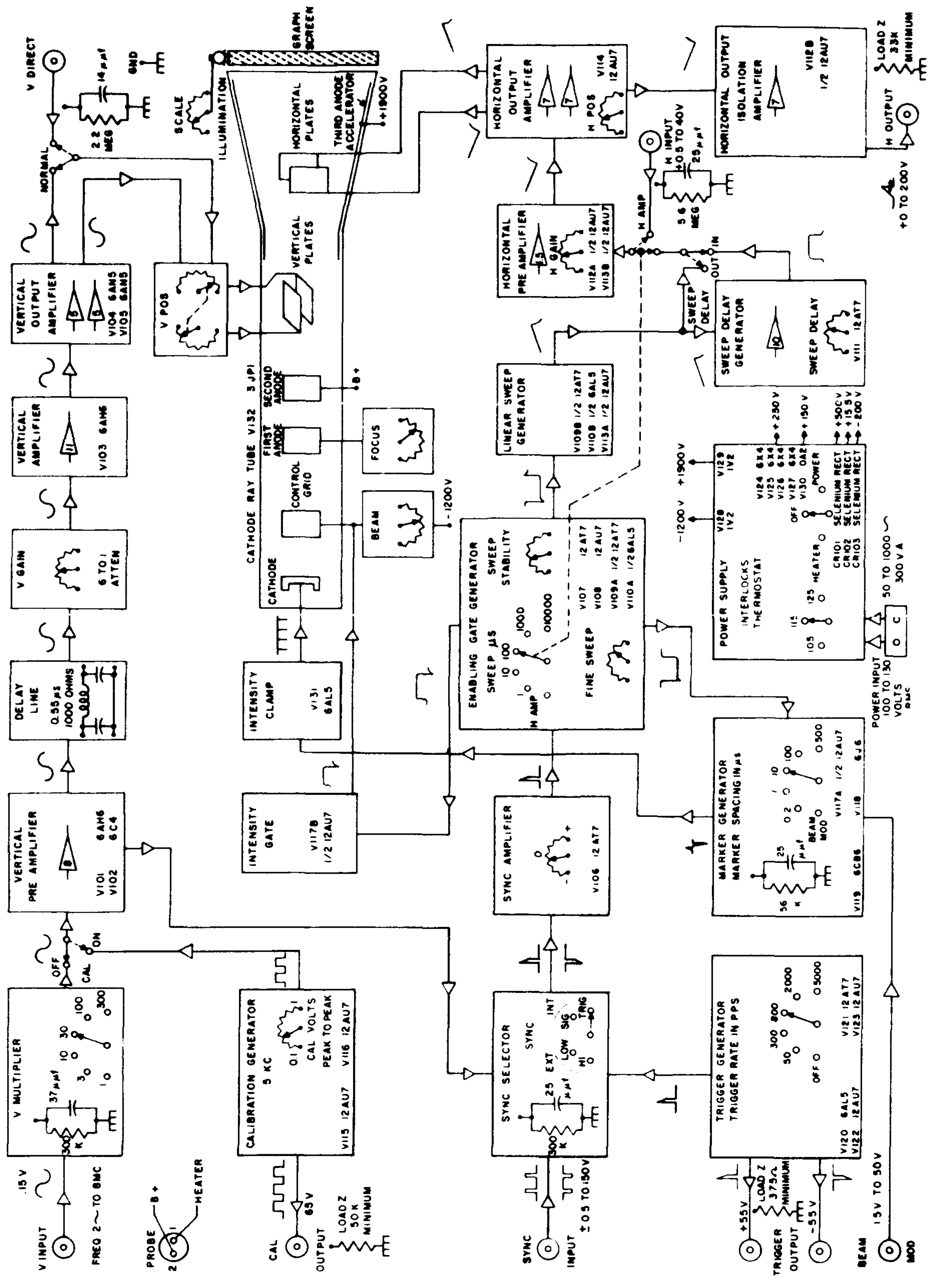

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Figure 7-10.—Block diagram of oscilloscope AN/USM-24.

the vertical input jack to the vertical plates of the CRT with the desired amplification, but with no appreciable change in its waveform. However, control over the magnitude of the signal is afforded in order to allow the instrument to handle a wide range of signal amplitudes. The signal must also be delayed sufficiently to permit the linear time base, the markers, and the intensification gate to start functioning properly before the signal reaches the vertical plates of the CRT.

Signals from 0.10 to 150 volts can be coupled directly to the input jack; signals from 9 to 300 volts may be connected to the vertical deflection plates of the CRT through the V direct terminal on the back of the oscilloscope. The frequency response curve for the vertical amplifier is essentially flat from about 30 cycles to 2 megacycles.

The R-C network in the V multiplier has a constant impedance equal to 300 k-ohms resistance shunted by 37$\mu\mu$f capacitance. The voltage divider is frequency compensated so that no distortion of the input signal results within the pass band of the vertical channel. The V multiplier switch has six positions: times 1, 3, 10, 30, 100, and 300. Voltages, as read on the CAL potentiometer (to be discussed later) are multiplied by the associated setting of the V multiplier switch for the purpose of calibrating the incoming signal. When Test Lead CG-883/USM-24 is used, the final reading is multiplied by 10.

The vertical preamplifier and delay circuit consist of a pentode amplifier and triode coupled to a delay line. The gain of the pentode is approximately 16 and the gain through the triode to the delay line (cathode-follower arrangement) is 0.5. Thus, the overall signal gain is 8, as far as the information being supplied to the vertical amplifier is concerned. The sync signal is tapped off at the plate of the triode and fed to the sync selector. For this signal, the gain of the triode stage is unity, and the gain of the preamplifier is 16.

The delay line is a pi-type filter containing 50 sections and having an overall delay of 0.55 μs. Terminating the delay line is a wire-wound potentiometer (V gain), the inductance of which provides a constant termination impedance.

The vertical amplifier is so designed that a good frequency response with a gain of approximately 10 is achieved.

The vertical output amplifier is a push-pull stage, feeding into the vertical plates of the CRT through the vertical positioning controls.

HORIZONTAL CHANNEL.—The horizontal channel consists of the horizontal preamplifier, the horizontal output amplifier, and the horizontal output isolation amplifier. Positive-going signals from the time-base channel (composed of the enabling gate generator, the linear sweep generator, and the sweep delay generator) or from the H input jack are fed to the horizontal preamplifier.

The horizontal preamplifier is resistance-coupled, with the volume control in the plate circuit. The positive-going input becomes a negative-going output.

The horizontal output amplifier is a cathode-coupled, push-pull stage. By the use of the horizontal output isolation amplifier, signals that have passed through the horizontal preamplifier and the horizontal output amplifier may be fed to an external circuit without affecting the operation of the oscilloscope.

INTENSITY CHANNEL.—The tube in the intensity-gate stage receives at its grid a positive gate pulse from the enabling gate generator. The output (positive going) from the cathode is fed to the control grid of the CRT. In the intensity-gate stage, the circuit constants are such that the tube acts as a limiter and feeds a constant-amplitude, positive-gate pulse to the grid of the CRT.

TIME-BASE CHANNEL.—The time-base channel consists of an enabling gate generator, which produces a gate pulse whose duration may be varied from 1.2 to 120,000 μs; a linear-sweep generator, which produces a linear sweep as controlled by the enabling gate generator; and a delayed sweep generator, which can be used to take any 10% portion of the linear sweep and magnify it to fill the screen of the CRT. The enabling gate generator can be operated either in a trigger (trigger supplied by the sync amplifier) or in a repetitive condition.

SYNCHRONIZATION CHANNEL.—The synchronization channel consists essentially of a selector switch (sync selector) that permits the selection of an external sync, internal trigger positive pulses from the trigger rate generator, or sync signals as developed in the vertical preamplifier.

MARKER CHANNEL.—The marker channel consists basically of a cathode-driven multivibrator, a gating tube, a marker amplifier, and a means of selecting markers.

TRIGGER CHANNEL.—The trigger channel circuit consists essentially of a free-running multivibrator (in the block marked trigger generator) for determining the repetition rate and a blocking-tube oscillator for producing trigger pulses.

CALIBRATION CHANNEL.—The calibration generator consists of a multivibrator operating at 5 kc and an out-put system. The potentiometer has a calibrated scale for adjusting voltages from 0.1 to 1 volt. The calibration switch connects either the vertical signal or the calibrated voltage to the vertical preamplifier.

DETERMINING THE AMPLITUDE AND RISE TIME OF INPUT PULSES WITH THE AN/USM-24.—These two basic measurements, the determination of (1) the amplitude and (2) rise time of a pulse, are given to illustrate the use of the equipment. The steps necessary for checking the amplitude are indicated in figure 7-11 by the circled numbers; the numbers enclosed in blocks indicate the necessary steps for checking the rise time.

The pulse amplitude may be checked as follows:

1. Set V MULTIPLIER to 1.
2. Set V GAIN half way.
3. Set SWEEP μs to H AMP.
4. Set SWEEP DELAY to OUT.
5. Set H GAIN to extreme CCW.
6. Turn HEATER-OFF POWER switch to POWER.
7. Adjust BEAM, FOCUS, H POS, and V POS for a well-defined spot located in the center of the screen.
8. Connect Test Lead CG 883/USM-24 to V input and apply to circuit under test.
9. Readjust V MULTIPLIER and V GAIN controls for a 1-inch deflection.

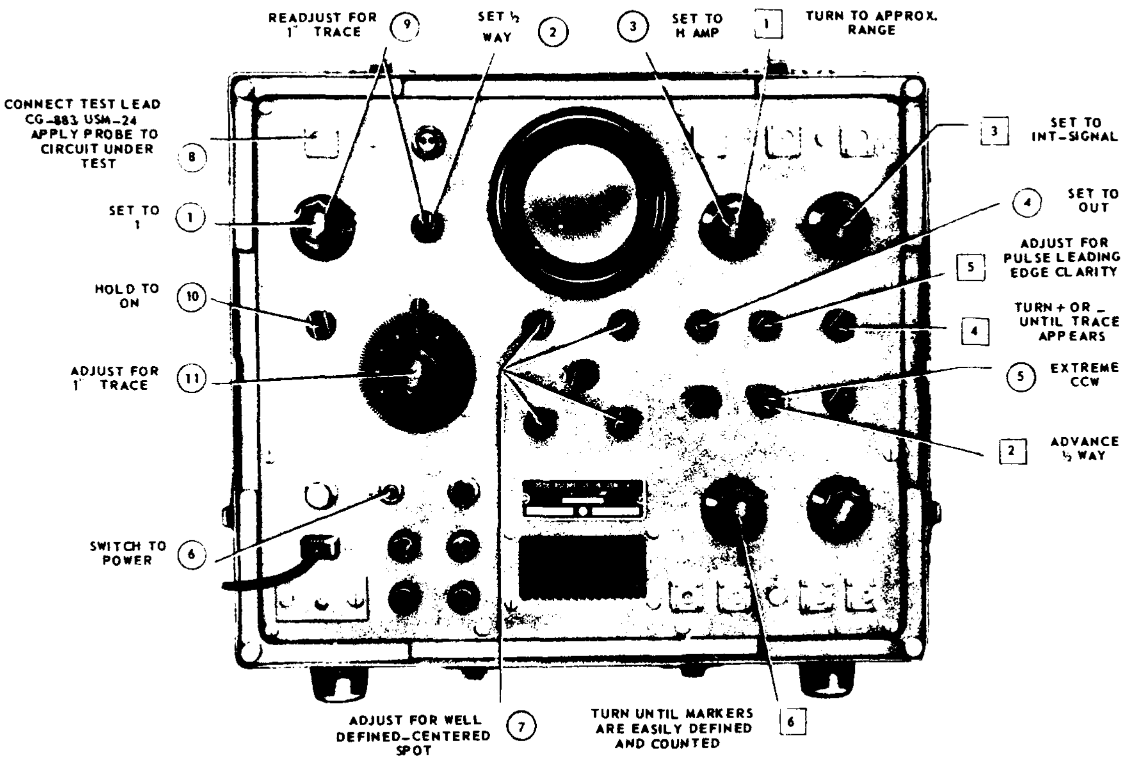

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Figure 7-11.—Control settings for basic measurements.

10. Throw and hold the CAL switch to the ON position.

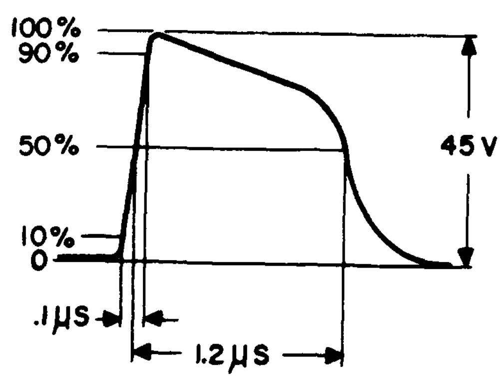
11. Adjust CAL VOLTS control for a 1-inch deflection; release CAL switch.

12. Multiply the CAL VOLTS dial reading by the V MULTIPLIER setting. Multiply the product by 10 (Test Lead CG-883/USM-24 has a 10:1 attenuation factor). The product of these three figures indicates the peak-to-peak voltage of the signal.

The rise time may be checked as follows:

1. Turn SWEEP μs switch to the range most likely to encompass the duration of the signal being viewed. (Test lead CG-883/USM-24 is applied to the circuit under test.)
2. Advance the H GAIN control half way.
3. Set SYNC switch to INT signal.
4. Advance SYNC control in + or - direction (depending upon polarity of signal being viewed) until horizontal trace appears.
5. Adjust FINE SWEEP control until leading edge of pulse is clearly defined on the screen. At this point it may be necessary to readjust the SYNC control.
6. Turn MARKER μs switch until the markers that appear on the leading edge of the pulse are sufficient in number to be sharply defined and counted between 10% and 90% of the total pulse amplitude.
7. Count the number of markers and multiply by the setting number of the MARKER μs switch. The product will be an indication of the rise time (in microseconds) of the measured pulse. Rise time is illustrated in figure 7-12.

In a radar system there are certain time delays that occur within the radar equipment



1.97
Figure 7-12.—Trigger-generator output pulse.

itself between the time the system is triggered and the time the echo pulse arrives at the indicator. Most of the delay is within the receiver; but some delay occurs in the transmitter and in the transmission line. The total delay may be equivalent to a range of 150 to 350 yards. This means that a target actually at zero range would be erroneously indicated (because of these delays) at a range of 150 to 350 yards. Zero error must be corrected after the time delay in the circuit has been determined. There are several methods of determining zero error. The most reliable is the fixed-target method in which a fixed target at a known range is used.

The synchroscope method, however, is one of the simplest. This method does not require a fixed radar target, and fairly accurate results may be obtained.

The test setup is shown in figure 7-13. In this arrangement the synchroscope horizontal sweep is triggered by the radar system trigger. A fast sweep of about 2 μs per inch is used, and the sweep must be carefully calibrated so that the number of microseconds each inch represents is known.

Trigger pulses that are used to start the range-marker circuit in the radar indicator are fed to the synchroscope vertical amplifier input. The vertical gain is set to provide a 1/2-inch (vertical height) pulse, and the leading edge of the pulse is marked on the scope.

Next, the trigger pulses are removed, and the radar receiver output is fed to the vertical amplifier input. The radar receiver local oscillator is detuned so as not to overload the synchroscope. The radar transmitter pulse will shock-excite the local oscillator at the receiver sufficiently to produce an i-f signal. Thus the pulse from the receiver is delivered to the synchroscope shortly after the trigger pulse is initiated. The vertical gain control is adjusted to provide a 1/2-inch pulse from the receiver when the receiver gain is set to produce about 1/8 inch of noise.

The leading edge of the pulse is again carefully marked on the scope. The distance between the two marks may be converted from microseconds to yards. This interval represents the time delay between the time the system is triggered and the time the receiver pulse arrives at the indicator. This figure is the zero error. This error is corrected for by adjustments in the range-marker circuit.

Typical measurements made with the synchroscope are included in the Maintenance

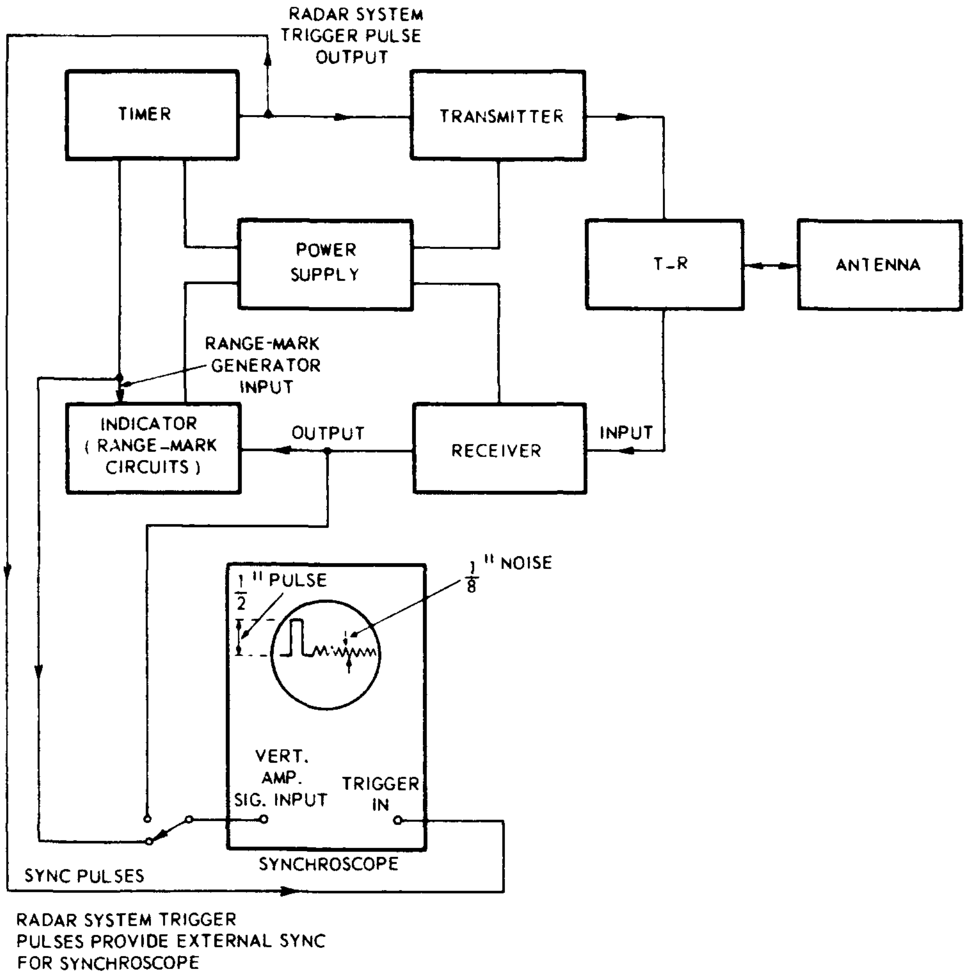


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Figure 7-13.—Test setup for zero-error determination.

Standards Books for the various radar sets—for example, the AN/SPS-8. The measurements are made semiannually, or more often if necessary. Typical measurements include the amplitude and time duration of the input trigger pulses.

The amplitude and time duration of the input trigger to the trigger amplifier chassis are determined by applying the trigger to the vertical input of the oscilloscope. The amplitude and time duration of the pulses are determined by observing the waveforms on the screen and the setting of the controls on the synchroscope. The amplitude should be between 15 and 30 v, and the time duration should be between 2.5 and 3.5 μs.

The same measurements are also made of the amplified trigger. The time duration should be the same, but the amplitude of the trigger pulse should be between 45 and 60 v.

The amplitude and time duration of the modulator pulse are also determined by the synchroscope. The modulator pulse is connected to the vertical input of the synchroscope, and the amplitude and time duration of the waveform determined by observation. The time duration should be between 0.5 and 1.5 μs and the amplitude between 45 and 60 v.

The amplitude and time duration of the charging waveform (the waveform fed to the pulse network) are likewise, determined. In this case the signal is connected from the charging waveshape jack to the vertical input of the synchroscope. The time duration should be between 950 and 1050 μs and the amplitude between 15 and 35 v.

Finally, the synchroscope is used to make sensitivity time-control measurements. The function of the sensitivity time-control (STC)

function of the sensitivity time-control (STC) circuit is to eliminate saturation effects caused by strong echoes from nearby targets. This circuit reduces receiver gain appreciably for a short time interval immediately after a transmitted pulse and then allows the gain to return gradually to the value normally determined by the setting of the receiver gain control. The waveform of the output signal of the STC circuit is indicated in figure 7-14. The signal is a negative voltage with a trailing edge that decays exponentially with time. This voltage is superimposed upon the negative gain-control voltage applied to the i-f amplifier portion of the radar receiver in order to control the receiver gain in accordance with the indicated waveform. The signal is obtained between terminal 6 and ground of the sensitivity time control unit (a part of the radar) and applied to the vertical input of the synchroscope. The time duration should be between 140 and 150 μs and the voltage amplitude between 5 and 10 v.

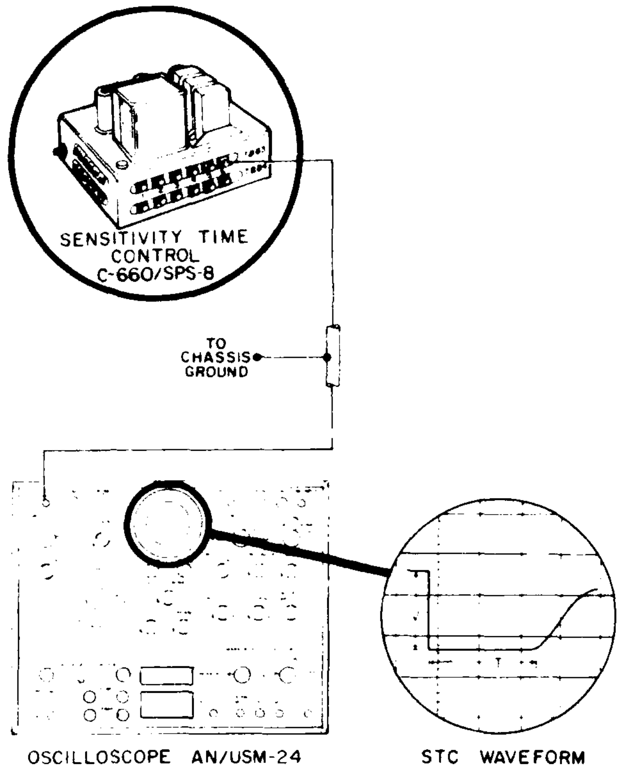

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Figure 7-14.—Radar sensitivity time-control measurements.

THE ECHO BOX TS-275/UP

Good radar performance is of vital importance because radar is the eye that the Navy depends on to detect enemy ships and planes long before they are detected by other methods. It has failed to accomplish this purpose if attacking enemy craft are detected too late for effective countermeasures to be taken. It is therefore extremely important that radar installations be maintained so that they always operate close to their maximum efficiency, and technicians should spare no effort in making this possible.

The ECHO BOX is one of the most important single test instruments for indicating the overall radar system performance. This results from the fact that the echo-box indication reflects the combined relative effectiveness of the transmitter as a transmitter of energy and the receiver as a receiver of energy.

The echo box, or resonance chamber, consists basically of a resonant cavity, as indicated in figure 7-15, A. The resonant frequency of the cavity is determined by the size of the cavity (the larger the cavity, the lower the frequency); and this, in turn, is determined by the position of the plunger. The accurately calibrated tuning mechanism controls the position of the plunger and indicates on a dial the resultant resonant frequency, or data that permits the technician to determine the frequency with great accuracy by consulting a set of curves.

Energy is coupled into the cavity from the directional coupler (or pickup dipole) by means of an r-f cable connected to the input loop. Energy is coupled out of the cavity to the rectifier and the microammeter by means of the output loop. The amount of coupling between the echo box and the crystal rectifier can be varied by changing the position of the output loop. A schematic diagram of the output circuit is shown in figure 7-15, B. The energy picked up by the loop is rectified, filtered, and applied to the meter.

A front view of a typical echo box (TS-275/UP) is shown in figure 7-15, C; the method of connecting the echo box in a radar system is shown in figure 7-15, D. An exploded view of this echo box is shown in figure 7-16. The box consists of a cast bronze cavity cylinder with removable bronze end plates. The movable plunger is actuated by means of the adjusting screw and the inner dial through the water-tight bellows. The gearing between the inner dial and

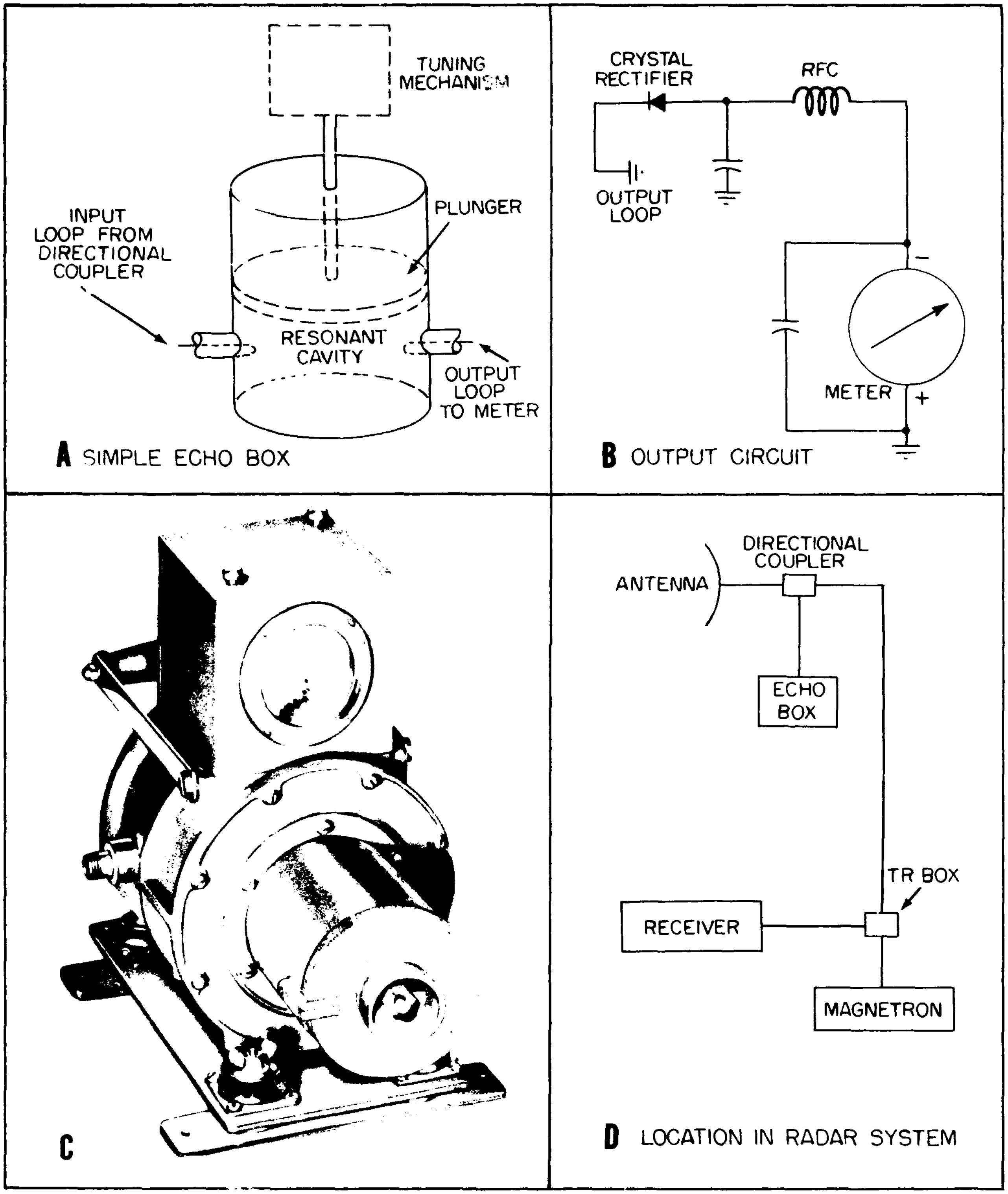

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Figure 7-15.—Echo box.

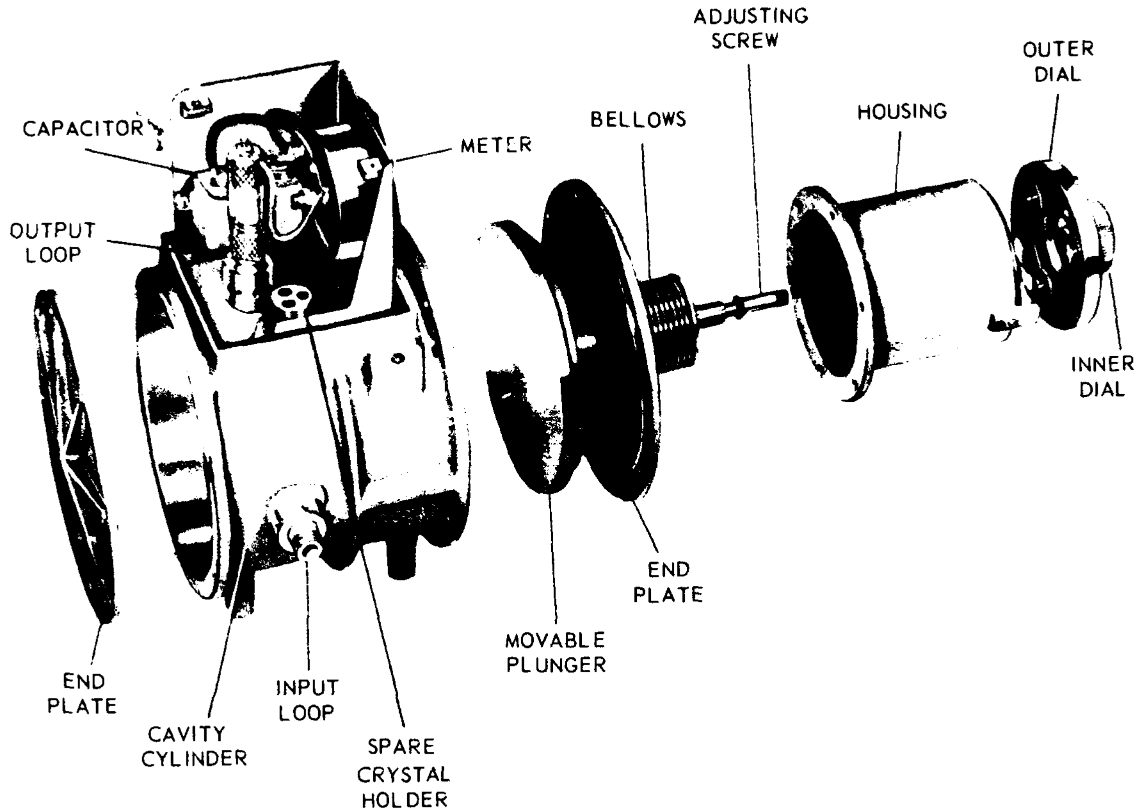

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Figure 7-16.—Exploded view of the TS-275/UP echo box.

the outer dial is so arranged that the outer dial travels the amount of one of its divisions while the inner dial makes one revolution (10 major divisions or 100 minor divisions). The gears merely operate the outer dial and have no connection with the driving of the plunger, and therefore do not cause backlash.

The indicating meter, the filter capacitor, and the spare crystal holder are mounted on top of the cavity cylinder.

The input and the output loop connectors project from the cavity cylinder.

Methods of Connecting

Either of two methods may be used to connect the echo box to the radar. A pickup dipole may be used, but more generally a directional coupler is used, as in figure 7-15, D. The method of installing the pickup dipole is described in the TS-275/UP instruction book (NavShips 900,825).

Much of the information contained in this instruction book is of a general nature and will be very helpful to anyone desiring practical information on the use of echo boxes.

A directional coupler is commonly included in the r-f plumbing of radar sets. This echo box is designed to be used with directional couplers having a coupling loss of 20 to 35 decibels on the usual radar in the frequency range covered by this echo box. The exact value depends on the radar.

Frequency Calibration

The echo box dial is read by reading the middle dial number and then the inner dial number. Figure 7-17, A, shows an example in which the reading is three two point six five (32.65). Each major division on the inner dial is one-tenth of a revolution, and each smaller division is one-hundredth of a revolution.

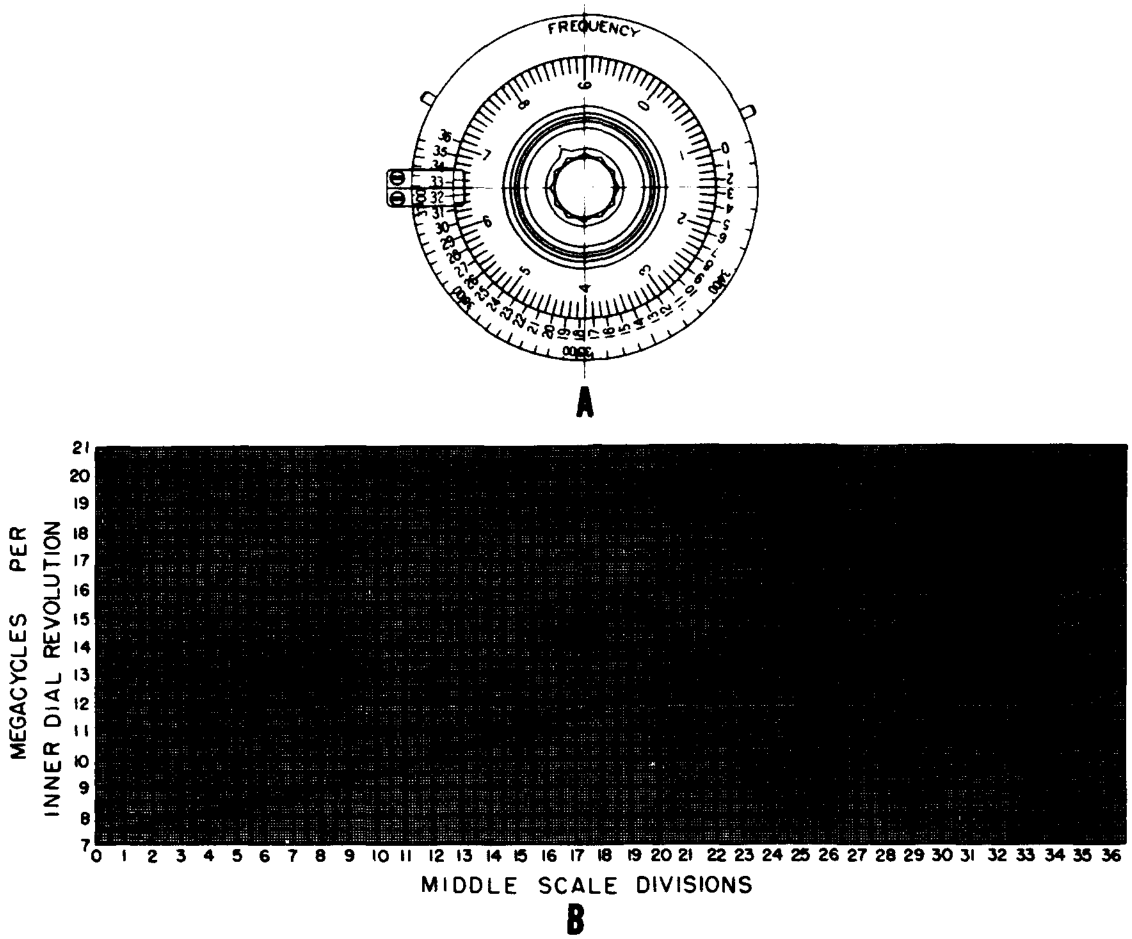

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Figure 7-17.—Reading the dial.

Each division of the middle dial represents one complete revolution of the inner dial.

The frequency calibration curve in figure 7-17, B gives the tuning rate of the echo box with any setting of the tuning dial. The method of using the curve may be best explained by giving an example. Assume that a radar under test is supposed to be tuned to a frequency of 3607 mc. (The direct frequency calibration, marked in red on the instrument, is provided on the outer portion of the outer dial.) The echo box is found to be in resonance when the tuning control is at 27.5 (middle dial divisions) rather than the expected 26 (opposite 3607 mc on outer dial). Obviously, the radar is transmitting on a frequency 1.5 inner dial revolutions higher than intended. From figure 7-17, B, the tuning rate is found to be 15.5 megacycles per (inner) dial revolution. The radar is thus transmitting on a frequency 15.5 x 1.5, or 23.25 mc too high.

Ringtime

Some of the energy generated by the radar transmitter is picked up by the echo box via the directional coupler. This energy excites oscillations in the echo box that persist for some time after the end of the radar pulse, much in the fashion of an echo that persists in a large room after a loud noise. As this echo dies down, a part of it is fed back into the radar receiving

system, again via the directional coupler. This causes a saturated signal to appear on the radar indicator, which is known as RINGING. The longer this ringing extends the better the performance of the radar—that is, the more powerful the transmitter is and/or the more sensitive the receiver is.

The length of time the echo box SHOULD ring under the particular conditions of the test (called the EXPECTED RINGINGTIME, or RINGTIME) may be compared with the ringing time observed, to determine whether the radar is performing well or not.

The ringtime to be expected on a good radar depends on the particular type of radar being tested; on the way the echo box is installed—that is, for example, whether a directional coupler or a dipole is used, and on the length and type of cable used; on the individual ringing ability of the particular echo box employed; on the frequency of the radar; and on the temperature of the echo box at the time of the test. Corrections are made for all of these factors according to the procedure given in the instruction book for the echo box being used.

An echo box without correction may be used for the purpose of detecting a CHANGE in the performance of a radar. The ringtime is simply noted and compared from day to day. It should be recognized that these readings do not permit the comparison of a particular radar with a standard of performance, and thus to tell whether more may be expected from a radar than its past performance would indicate.

Ringtime Measurements

Because ringtime measurements constitute the most valuable single feature of the echo box, it is essential that they be carried out properly and with due regard for the necessary precautions. Ringtime measurements are made on the A-scope or on the PPI, both methods of which are discussed later.

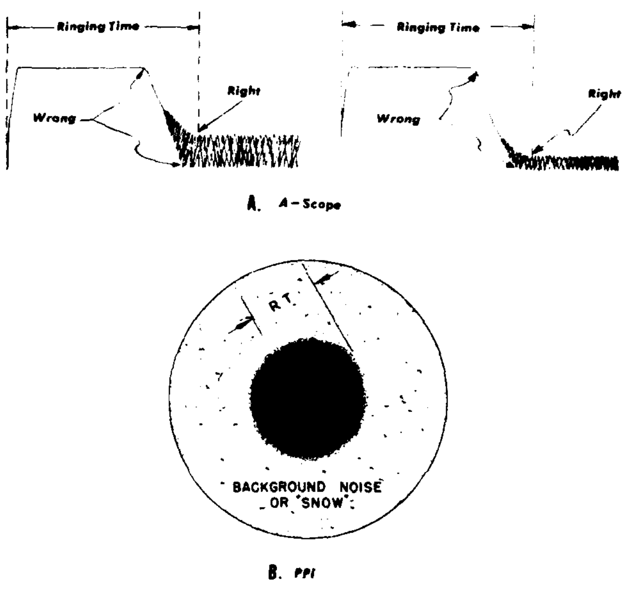
In measuring the ringtime, the technician should make sure that it is the echo-box ringtime and not some fixed-target echo or block of echoes that is being received. This condition can be determined by adjusting the radar gain control and noting if there is a back and forth movement of the ringtime on the scope. The echo box echo will change in range; fixed target echoes, however, will not change in range, only in amplitude.

In order to obtain accurate results, every ringtime measurement should be repeated at least four times, and the readings averaged. Care must be taken to ensure that all readings are accurate. If two or more technicians use the same echo box, they should practice together until their ringtime measurements agree.

Radars have a tendency to drift slightly in frequency. When this occurs, the echo box becomes detuned and accurate ringtime measurement is difficult. Therefore, it is necessary when making ringtime measurements for longer than a very few minutes to retune the echo box from time to time.

The radar antenna should not be pointed at a mast or other nearby obstruction because proximity effect may cause the transmitter to change frequency.

A-scope presentation of ringtime is indicated in figure 7-18, A. The receiver gain should be set so that the 'grass' or noise is one-quarter to one-third the total saturated signal height on the A-scope. When this is done, a good pattern results, such as either of those shown in the figure. In the event that no 'grass' can be seen, the gain of the radar i-f is inadequate and repairs should be undertaken.



55.121(70)A
Figure 7-18.—A-scope and PPI presentation of ringtime.

The exact end of the ringtime occurs at the furthest point to the right at which the TOP of the 'grass' is noticeably above the general level of the rest of the 'grass.' Do NOT judge ringtime by the BOTTOM of the 'grass' or by the end of the saturated portion of the ringtime because these items are influenced by the receiver gain setting and other factors.

Setting the gain too high or too low may make it difficult or impossible to read the ringtime with accuracy. (It is essential that 'grass' be present.)

An A-scope indicator measurement of ringtime is usually best performed when the radar antenna is stopped.

PPI presentation of ringtime is indicated in figure 7-18, B. In this instance, the same general principles apply as did in the case of the A-scope presentation.

The following procedure should be followed. With the radar antenna rotating, set the receiver gain at a minimum and adjust the intensity (bias) so that there is a very slight radial trace on the PPI indicator. Increase the receiver gain until the PPI-indicator area seems to be just half covered with flecks of snow.

A PPI ringtime pattern, with proper receiver gain adjustment (and the radar antenna rotating), is shown in the figure. In this case, the echo box is used with a directional coupler.

It should be emphasized that the end of the ringtime signal is NOT at the place where the bright or saturated part of the signal ends, but where the fainter portion of the signal disappears into the background noise. Therefore, when reading the ringtime on a PPI indicator, be sure to observe to the extreme edge of the grass and NOT JUST TO THE END OF THE BRIGHT PORTION OF THE PATTERN. Read to the last point at which the 'snow' is unusually bright. As indicated in figure 7-18, B ringtime (RT) is measured from the center of the pattern to the outer edge.

Spectrum Analysis

Every time a radar transmitter generates an r-f pulse, it produces a certain amount of r-f energy in the form of electromagnetic waves. Not all of these waves, however, are of the same frequency; in fact, only a small portion of them have exactly the same frequency as that to which the transmitter is tuned. The rest of the radiation is at slightly higher or slightly lower frequencies, forming the sideband frequencies. This is the natural result of pulse modulation and cannot be avoided.

Actually, the radar energy is distributed more or less symmetrically over a band of frequencies, as illustrated in figure 7-19, A. This frequency distribution of energy is known as the SPECTRUM. An analysis of its characteristics may readily be carried out with the aid of the echo box.

When properly performed and interpreted, a spectrum analysis will disclose maladjustments and troubles that would otherwise be difficult to locate. It is important, therefore, that the technician who uses the echo box be able to carry out a spectrum analysis and understand the results.

When a spectrum analysis is to be made, the tuning control of the test set (fig. 7-15, C) is first turned until a maximum output meter deflection is obtained, then the tuning control is turned slowly from a point well below this maximum to a point well above it.

While this is being done, the output meter readings are noted for various settings of the tuning control. It is good practice to cover the frequency range desired by turning the tuning knob slowly in the same direction to each new position, not by turning it back and forth. This is done to minimize any possible error due to backlash. A reading should be taken about every 0.02 revolution of the tuning knob.

Finally, an accurate graph is constructed with the meter readings plotted against the tuning control dial settings. The resulting graph should resemble one of those shown in figure 7-19.

A radar transmitter in satisfactory condition should give a spectrum curve similar to curve A or curve B. Good curves are those in which the two halves are symmetrical and contain deep, well-defined minimum points on both sides of the main peak.

A curve without deep minima, as in curve C, indicates that the transmitter output is frequency modulated during the pulse. This may be due to the application of a negative pulse to the magnetron that does not have sufficiently steep sides or flat extremities. It may also be due to a transmitter tube that is unstable or is operated with improper voltage, current, or magnetic field.

When the spectrum is extremely irregular, as in curve D, it is an indication of severe frequency modulation. This will probably cause trouble in the receiver automatic frequency

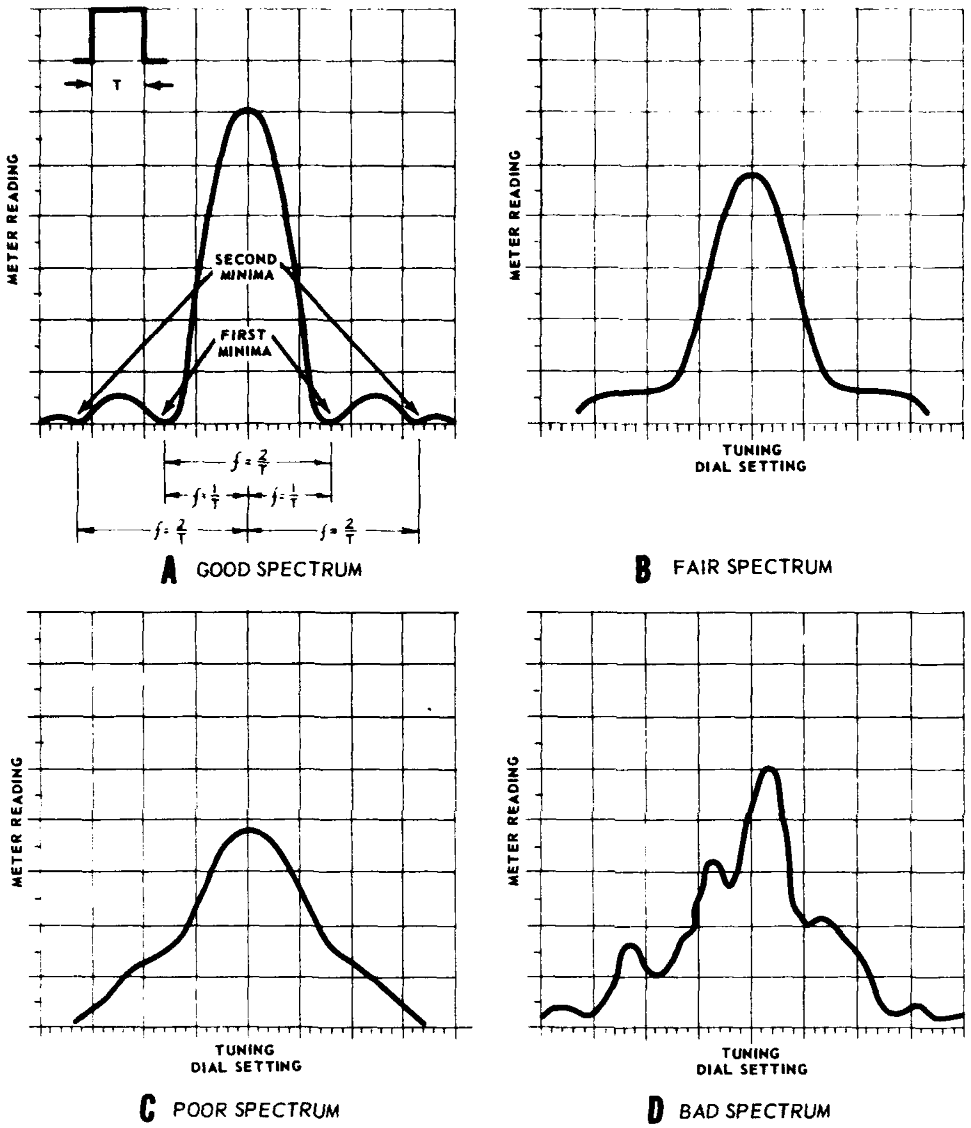


Figure 7-19.—Typical radar spectra.

control as well as general loss of signal strength. When the spectrum has two large peaks, quite far apart, it indicates that the transmitter tube is double moding, perhaps because of unwanted standing waves in the transmission line or a bad transmitter tube. A faulty spectrum can often be improved by adjustment of the transmission line stubs or by replacement of the transmitter tube. Standing waves may be due to a faulty line connection, a bad antenna rotating joint, or obstructions in the line.

In the case of a good or fair spectrum curve with sharply defined minima on both sides of the main peak, the distance between these two minima is proportional to the duration of the transmitted pulse. Because the duration of the pulse determines the distribution of power in the sideband frequencies, the pulse length

may be found from the spectrum graph. The procedure is to determine the distance in megacycles between the minima on either side of the main peak. These minima are separated by a frequency (in megacycles) equal to $\frac{2}{T}$, where T is the pulse length in megacycles and $\frac{1}{T}$ is the number of sideband frequencies contained in either upper or lower sideband (from the carrier frequency to the first minimum on either side of the carrier). Expressed as an equation,

$$\text{pulse length in microseconds} = \frac{2}{\text{distance between minima in megacycles}}.$$

Suppose, for example, that the echo box is being used to check the pulse length of a radar. The graph of the spectrum is plotted, and the tuning distance between the minima is from 17 divisions on the middle dial (fig. 7-17, A) to 17.17 divisions (17 divisions on the inner dial). From figure 7-17, B it is found that for the particular frequency range in question (3480-3490 mc) the echo box tunes at a rate of 11.65 mc per revolution (corresponding to 17 divisions on the middle dial). The frequency span between minima is

$$11.65 \times 0.17 = 1.98 \text{ mc.}$$

Applying the equation given in the last paragraph, the pulse length in microseconds $= \frac{2}{1.98} = 1.01$ microseconds. The value thus calculated can be readily compared to the standard value for a radar of the type under test by reference to the radar manual. Any great change in the test value compared to the standard value indicates an improper pulse length.

The shorter the pulse length, the wider will be the frequency band that the signals occupy. This effect will appear on the graph as a wide span between the first minima of the spectrum curve.

An abnormally narrow spectrum shows that the transmitted pulse is too long. Such a pulse could result in a long ringtime and high power reading on the echo box output meter, thus falsely indicating superior system performance.

Power Output

At the time of installation, the meter reading on the echo box, TS-275/UP, should have been set between 40 and 80 divisions (by adjusting the orientation of the output loop) while the echo box was tuned to resonance with the radar transmitter.

The output meter reading is closely proportional to the average radar power picked up by the echo box and to the transmitter pulse length, when the echo box is tuned to the maximum output signal of the spectrum. If the pulse length is long, the spectrum curve is consequently high and narrow, and the meter reading is high. Where the pulse length is shorter, the spectrum curve is flatter and the meter reading will be lower.

The power output of a radar is generally good if the transmitter current is normal. Loss in the transmission line may cause loss of power, and in the event that low power is observed at the antenna of the radar by means of a pickup dipole and echo box, the transmission line may be suspected. Because of the high initial cost of radar transmitting tubes, the echo box and its accessories should be checked carefully before discarding such a tube. Transmitter tuning stubs are NEVER adjusted for maximum power output, as indicated at the echo box. These stubs provide a transmitter frequency adjustment, the net effect of which is observed at the receiver indicator rather than at the echo box. The correct procedure for checking the radar frequency is described in this chapter.

Other Tests

GENERAL PROCEDURE.—A variety of radar equipment checks can be carried out with the aid of the echo box. The exact nature of these tests, as well as the detailed methods of procedure, may vary to some extent between different types and models of radar equipment. The typical procedures given in the following paragraphs will be useful in establishing test routines to be followed in radar maintenance. Practice and experience may suggest variations as the technician becomes more familiar with the use of the echo box.

In the testing procedures outlined in the following paragraphs it is assumed that the echo box is properly installed, and that the expected ringtime and output meter reading are known for the particular radar under test.

All measurements should be recorded in the radar log and/or on forms provided for this purpose. One such form for ringtime, from the Maintenance Standards Books, Part II Preventive Maintenance Checkoff for Radar Set AN/SPS-8, NavShips 91522.41, is included in figure 7-20. The figure includes complete instructions for making the test. Another form for listing echo box meter readings from the same publication is included in figure 7-21.

As a preliminary step in all tests, the radar equipment should be allowed to warm up fully to the normal operating temperature. The directional (or bidirectional) coupler or the pickup dipole (when used) should be correctly coupled to the echo box. All antijamming provisions (provisions to reduce the effects of the enemy jamming the radar) and the sensitivity time control, if provided, should be turned off.

OVERALL PERFORMANCE.—Adjust the echo—box tuning knob for a maximum reading of the output meter, indicating that the echo box is tuned to resonance with the radar. Then adjust the radar receiver local oscillator frequency for maximum ringtime on the indicator. Measure the ringtime as accurately as possible, preferably by taking advantage of at least four readings. Ringtime is most conveniently measured on an A-scope with the antenna stopped, and on a PPI-scope with the radar antenna rotating. Record the ringtime on the forms provided. Compare this figure with the corresponding value of the performance standard.

If the output meter and ringtime measurements are both satisfactory (compared with the expected values), the radar transmitter and receiver are both functioning well. If the meter reading is satisfactory but the ringtime is low, the radar receiver is the probable source of the trouble. Service the receiver, consulting the appropriate instruction book for the detailed procedure.

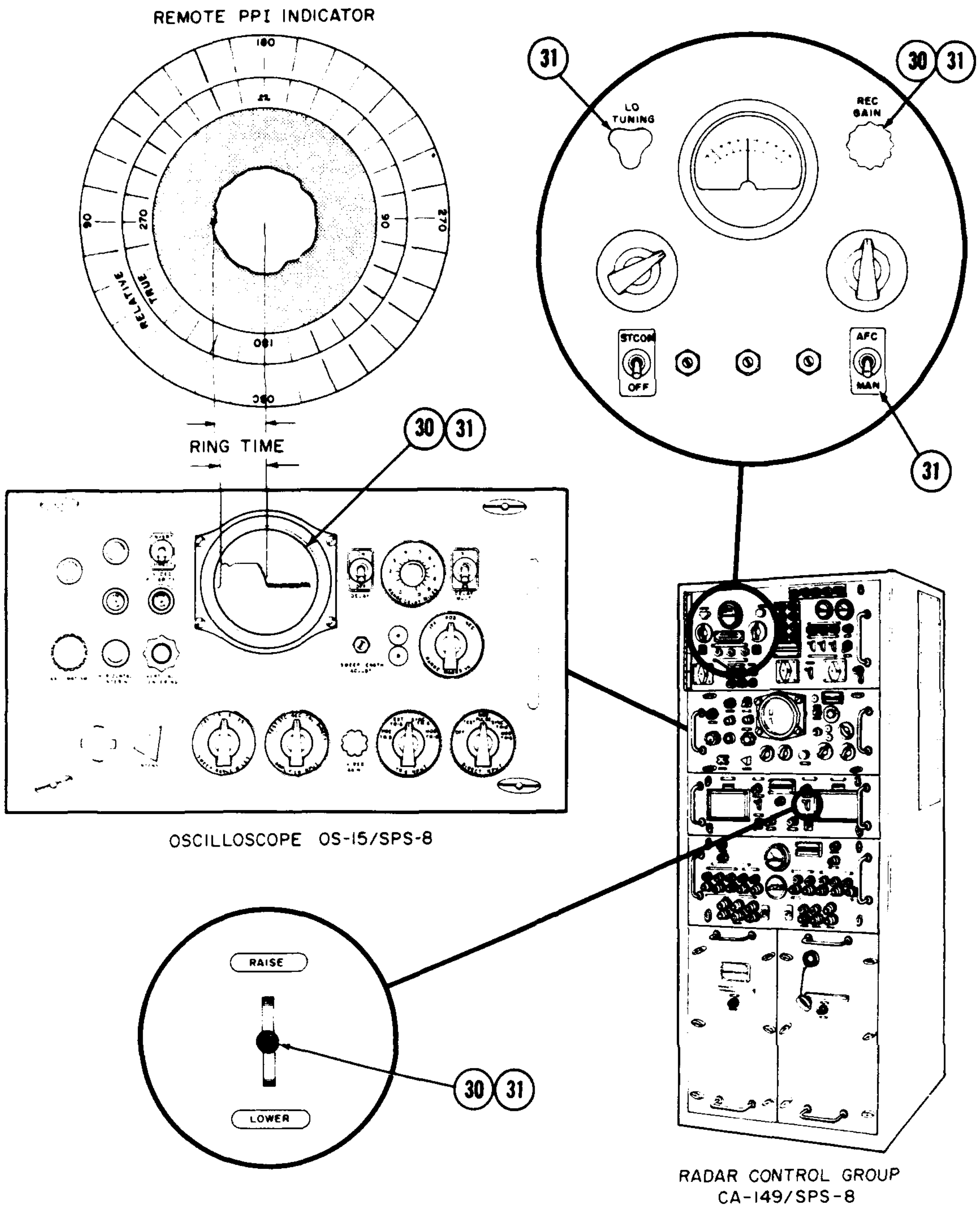
TRANSMITTER POWER.—The echo-box output meter reading is closely proportional to the average energy radiated from the radar on a particular frequency. The measurement of relative transmitter power is, therefore, a direct and simple procedure. Tune the echo box to resonance and then stop the radar antenna. Record the maximum reading on the output meter. This measurement, compared with the corresponding value on previous tests, gives an index of transmitter power. If the meter reading is satisfactory, the radar power output is good. If the meter reading and ringtime are low, the transmitter power output is low, and a spectrum analysis should be made, as previously described.

RADAR FREQUENCY.—To check the TRANSMITTER FREQUENCY, adjust the echo-box tuning knob for maximum deflection of the output meter, and stop the antenna. Read the tuning-knob scale and determine the transmitter frequency by reading the red calibration on the outer portion of the face of the outer dial, or by referring to the echo-box frequency calibration curve (fig. 7-17, B). If the transmitter frequency is found to be different from the frequency intended, the cause may be the transmitter tube or the transmitter tuning adjustments. Reference should be made to the appropriate instruction book.

To check the LOCAL OSCILLATOR FREQUENCY, the echo box is disconnected from the directional coupler (or pickup dipole). It is then coupled directly to the local oscillator output. (A special connector may have to be improvised to fit the local oscillator output of certain radars. It is desirable to insert 10 to 20 db of attenuation between the local oscillator and the echo box.) Adjust the echo-box tuning control for maximum deflection of the output meter. Read the tuning-control scale and, referring again to the echo-box calibration data, record the local oscillator frequency. The echo-box meter reading is likely to be excessive if attenuation is not inserted, and the output loop (fig. 7-15, A) should be adjusted to protect the meter (the loop may be adjusted with a wrench).

The DIFFERENCE BETWEEN THE TRANSMITTER AND THE LOCAL OSCILLATOR FREQUENCIES is easily checked by the curve in figure 7-17, B. It is necessary to have not only the correct frequency difference but also to have the local oscillator operating on the proper side (above or below) the transmitter frequency. This frequency difference is, in each case, identical with the frequency of the radar i-f amplifier. Using the tuning curve in figure 7-17, B, the technician can readily check the frequencies and determine whether the difference between them is correct.

To TUNE THE LOCAL OSCILLATOR, couple the echo box to the local oscillator. From



36.100(70)A

Figure 7-20.—Steps for recording ringtime.

STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD
30	Record radar ring time with AFC.	Set REC GAIN (R7142) for one-half inch of grass on Oscilloscope screen. Tune Echo Box with RAISE-LOWER switch (S7404) for maximum ring time indication of Oscilloscope screen. The ring time is obtained directly in yards on the remote PPI indicator. Rotate Antenna and set the range ring slightly beyond the solid echo portion of pattern as shown on illustration page.	Range Dial Remote PPI Indicator.	______ YDS (3200 or more)
31	Record radar ring time in manual tuning position.	Same as Step 30 except AFC-MANUAL switch (S7104) in MANUAL position, and LO TUNING (R7138) varied for maximum ring time.	Range Dial Remote PPI Indicator.	______ YDS (3200 or more)

STEP NO	30	31		30	31		30	31		30	31		30	31		30	31	
Month	JAN 19__			FEB 19__			MARCH 19__			APRIL 19__			MAY 19__			JUNE 19__		
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1																		
2																		
3																		
4																		
5																		
Month	JULY 19__			AUG 19__			SEPT 19__			OCT 19__			NOV 19__			DEC 19__		
Week	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init	Yds	Yds	Init
1																		
2																		
3																		
4																		
5																		

36.101(70)A

Figure 7-20.—Steps for recording ringtime—Continued.

the echo-box calibration data, find the echo-box setting for the correct local oscillator frequency, and adjust the echo-box tuning control accordingly. Then adjust the local oscillator, referring to the radar manual for the correct procedure, until the echo-box output meter shows maximum deflection. The oscillator is then approximately tuned to the correct frequency. Final tuning of the oscillator should be such as to produce maximum ringtime and proper radar crystal current.

ERRATIC TRANSMITTER OPERATION.—Adjust the echo-box tuning control for maximum deflection of the output meter with the echo box connected to the directional coupler, and stop the antenna. If the transmitter is operating normally, a good ringtime pattern will be displayed on the A-scope (fig. 7-18). If the ringtime is erratic, or extra background noise traces appear in the pattern, then the transmitter may be multiple moding (transmitting on two or more distinct frequencies) or failing

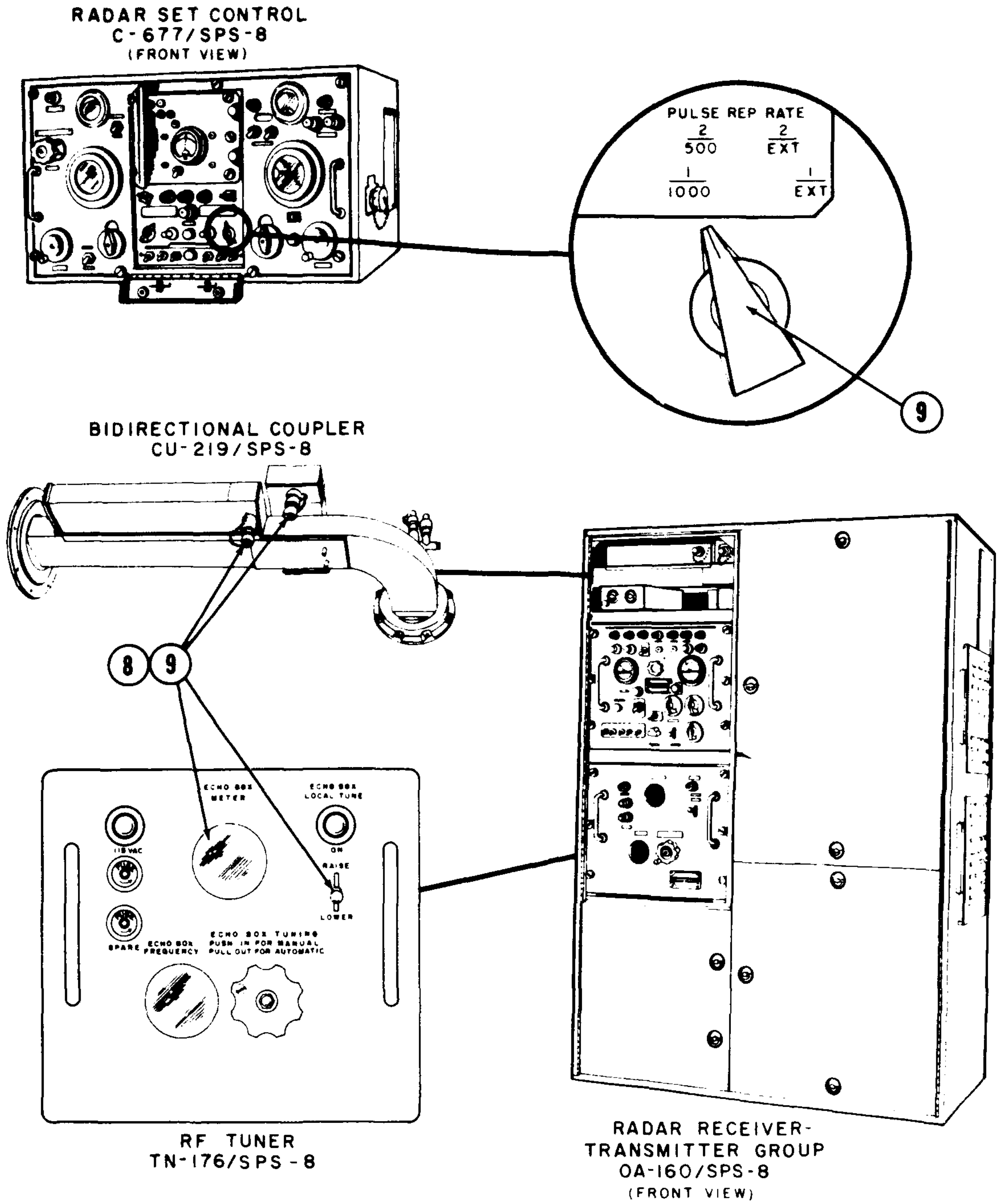


Figure 7-21.—Steps for recording transmit/receive ratio. 36.100(70)B

to fire on every pulse. This may be due to faulty pulsing; transmission-line troubles, especially arcing; or other causes. Examine the spectrum in order to help localize the trouble. Refer to the appropriate instruction book for help in correcting the trouble.

TRANSMITTER PULLING.—Magnetron frequency pulling results from a change in the loading as the antenna is rotated. As a check for magnetron pulling, turn off the automatic frequency control on the radar receiver. Adjust the echo-box tuning control for maximum

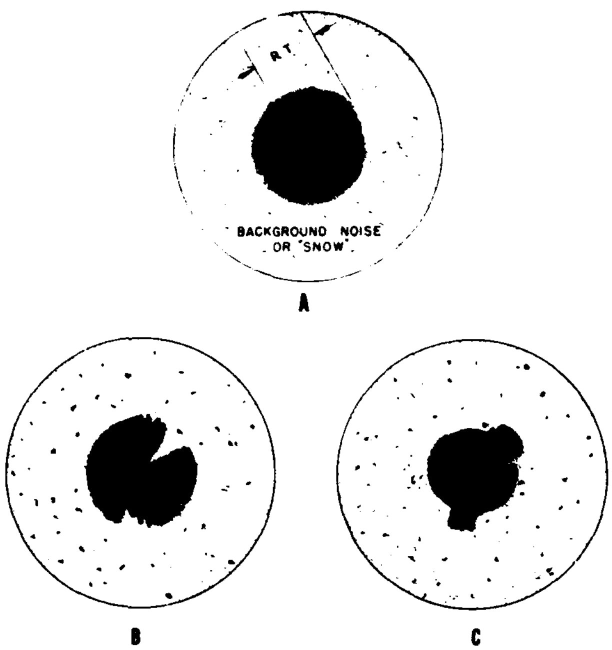
STEP NO.	ACTION REQUIRED	PRELIMINARY ACTION	READ INDICATION ON	PERFORMANCE STANDARD
8	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 1-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Connect echo box to J3007 on transmitter arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Connect echo box cable to J3008 on receiver arm of bidirectional coupler. Vary RAISE-LOWER switch (S3501) for maximum reading on Echo Box Meter. Note reading. Divide the first reading by the second reading and record the ratio.	Echo Box Meter First reading Second reading	Ratio (1.1 or larger)
9	Record Echo Box ratio as an indication of transmission line voltage standing wave ratio (VSWR) with a 2-microsecond pulse. (These ratios are inversely proportional; if actual VSWR is desired see interpolation curves in Section 6 of NAVSHIPS 91522 (A)).	Throw PULSE REP RATE switch (S6205) to 2/500 and repeat Step 8.	Echo Box Meter First reading Second reading	Ratio (1.1 or larger)

STEP NO.	1st QUARTER 19__			2nd QUARTER 19__			3rd QUARTER 19__			4th QUARTER 19__		
	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date	Ratio	Initial	Date
8												
9												

36.100(70)B

Figure 7-21.—Steps for recording transmit/receive ratio—Continued.

deflection of the output meter. With the radar antenna rotating, observe the pattern on the PPI indicator. If the transmitter is operating normally, a good ringing pattern will be seen, as in figure 7-22, A. If there are blank spaces on the PPI indicator or if the ringtime is reduced on certain azimuths, as in part B, then the transmitter is being frequency pulled. In such a case, the output meter reading will also fluctuate as the radar antenna is rotated slowly. Transmitter frequency measurements at several azimuths may also be used to confirm



55.121(70)B
Figure 7-22.—Indication of magnetron pulling.

this difficulty. The pulling may be caused by a bad rotating joint or by a reflecting surface near the antenna. Refer to the appropriate instruction book for corrective measures.

AUTOMATIC FREQUENCY CONTROL.—To determine whether the local oscillator is following the transmitter when it is pulled, first stop the antenna on an azimuth where the ringtime pattern is broken, and then retune the echo box to resonance. Rotate the radar antenna and again examine the PPI pattern. If the ringtime is now good on the azimuth at which the echo box was retuned (fig. 7-22,C), the AFC is in operation on that azimuth and the local oscillator is following when the transmitter is pulled. As may be seen in part C, the ringtime may have now decreased in those azimuths where it was originally good. If the AFC does not follow, the pulling may be excessive or the AFC may be at fault. If the ringtime is greatly decreased at certain azimuths, and the AFC does not follow, the radar must be considered inoperative at those azimuths and should be so reported.

A simple procedure will show whether the AFC is locked on the proper frequency. Stop the radar antenna and tune the echo box for maximum meter reading. Turn off the AFC switch and tune the local oscillator for maximum ringtime, thus putting the local oscillator in proper tune. Turn the AFC switch on again. If the ringtime decreases, even slightly, the AFC is locking on the wrong frequency, or is failing to lock. The proper instruction book should be consulted for corrective procedure. The probable cause of the AFC failure is a bad spectrum or the fact that the local oscillator is tuned to a frequency on the wrong side of the transmitter frequency. It is usually not advisable to tune the AFC circuit.

T-R BOX RECOVERY.—The time required to permit T-R (transmit-receiver switch) recovery is determined by the time it takes the T-R switch to deionize after each transmitter pulse. It is usually defined as the time required for the receiver to return to within 6 db of normal sensitivity after the end of the transmitter pulse. T-R recovery time is the factor that limits the minimum range of a radar because the radar receiver is unable to receive signals until the T-R switch is deionized. In various radar sets, the recovery time may vary from about 3 to 20 μs.

To test for T-R box recovery, adjust the echo-box tuning control for maximum deflection of the output meter, and stop the radar antenna. Adjust the A-scope for a good ringtime pattern, such as curve E in figure 7-23. Slowly and gradually reduce the radar receiver gain setting, or better, detune the local oscillator. A pattern will result, such as curve D in figure 7-23, having the same relative shape as curve E. Further slight reduction in gain setting will produce another pattern, such as curve C, again similar in shape to curve E. Continue until a change occurs in the slope of the curve, as in curve B. This point of change marks the T-R box recovery time of the radar, as indicated in the figure. For a good radar, the T-R recovery time should correspond to a range of one mile or less.

If the gain control is reduced still further, a greatly distorted pattern will appear, such as curve A in figure 7-23. This curve shows that the T-R box has not recovered. Refer to the appropriate instruction book for corrective procedures. If the above procedure does not produce a series of curves (as indicated) giving a T-R recovery point, and if the ringtime is short, then it is probable that the T-R recovery

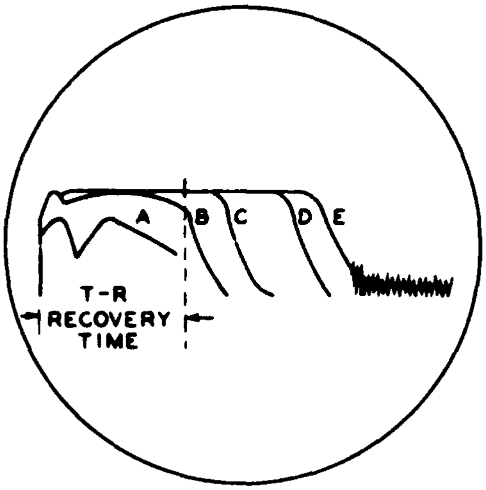


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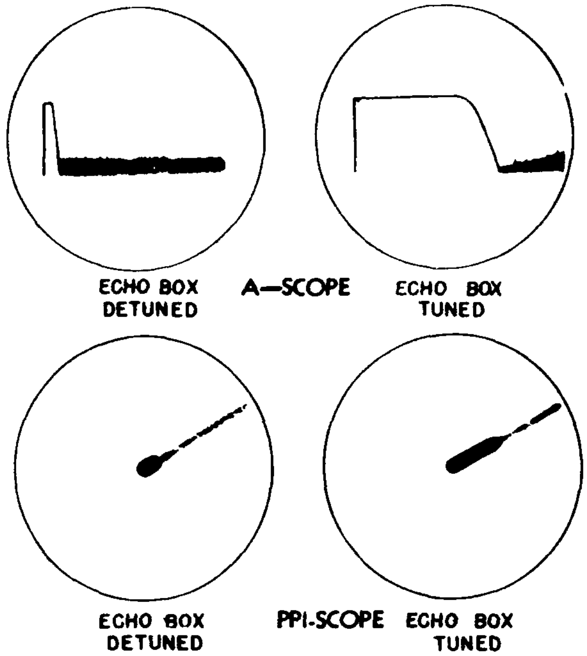
Figure 7-23.—Checking T-R box recovery.



55.119
Figure 7-24.—Receiver nonrecovery.

time is much too high (greater than the ringtime) and a new T-R tube is needed. Check the keep-alive current. The keep-alive current should be negative and between 0.1 and 0.2 ma.

RECEIVER RECOVERY.—Adjust the echobox tuning control for maximum deflection of the output meter, and stop the radar antenna. Then detune the echo box, and adjust the radar receiver gain control until the indicator shows a pattern similar to one of those illustrated at the left of figure 7-24. Now retune the echo box to resonance and again observe the indicator pattern. If the receiver recovery time is normal, the background noise will reappear immediately after the end of the ringtime pattern, and this noise will be approximately as strong as the noise previously observed with the echo box detuned. If the receiver recovery is slow, the noise will be weak and will not reappear for some time after the end of the ringtime pattern (see the right-hand portion of figure 7-24). In extreme cases of receiver nonrecovery, normal background noise may not reappear on the indicator at all. Receiver nonrecovery is usually an i-f tube or video defect which will make the radar susceptible to enemy jamming.

TRANSMISSION LINE LOSS.—Using the directional coupler, tune the echo box to resonance. Record the ringtime and the output meter reading. Disconnect the echo box from the coupler and connect it to the dipole (the proper location of the dipole is given in the instruction book; it is located at a position somewhere in the antenna radiation field). Again tune the echo box to resonance and again record the ringtime and the output reading. Comparing these measurements, while allowing for the normal difference due to the difference between the coupler attenuation and the antenna space loss (losses are indicated in tables in the echo box instruction book), an indication can be obtained of the loss in the radar r-f transmission line. If there is unusual loss in the radar transmission line, there will be greater differences than usual in the ringtime and also in the output meter reading. Repair or adjustments may then be undertaken.

Intermittent defects in the transmission line can often be found by rapping on the line while observing the echo box meter reading.

RAPID TROUBLESHOOTING CHART.—When the technician has become familiar with the test procedures and measurements, the echo box may be used for rapid troubleshooting.

Radar troubles may be more readily checked with the aid of the cause-and-effect chart of figure 7-25 which is essentially a summary of the information given on the use of the echo box as a test instrument.

FREQUENCY-POWER METER TS-230B/AP

Frequency-Power Meter TS-230B/AP measures the power (and frequency) of unmodulated and pulsed signals in the range from 8500 to 9600 mc ± 4 mc. It measures average power within the limits of 0.1 and 1000 mw (-10 to + 30 dbm). A front view of the meter is shown in figure 7-26.

A general idea of how the power-measuring circuit in the meter works can be obtained from the following consideration. The thermistor (fig. 7-27) is actually the heart of the power-measuring circuit. This circuit operates on the basic principle of applying the r-f power to be measured to a thermistor and observing the heating effects of that power in changing the thermistor resistance. A thermistor has a high negative temperature coefficient; that is, its resistance decreases rapidly as its temperature increases.

The thermistor is used in one arm of a balanced bridge so that any change in its resistance can be detected and measured. The thermistor is placed so that it will absorb r-f energy from the r-f field without applying r-f voltage directly to the bridge. Thus the d-c meter, M, is not subjected to an r-f voltage and the bridge is isolated electrically from the r-f source.

The power required to bring the thermistor to the right resistance for balancing the bridge varies from about 2 to 20 mw, depending on the individual thermistor and the surrounding temperature. This type of bridge is balanced when the meter reads zero. The condition of balance may be expressed mathematically as:

$$\frac{\text{thermistor resistance}}{\text{resistance of A}} = \frac{\text{resistance of B}}{\text{resistance C}}.$$

In the simplified circuit, the bridge is balanced by varying the d-c supply to the bridge, thereby heating the thermistor with enough d-c power to bring it to the right temperature so that its resistance will balance the bridge (meter reads zero). When the bridge has been balanced, the addition of power (either d-c or r-f) to the thermistor will, through the associated heating effect, unbalance the bridge and cause the meter to move up scale. The meter sensitivity is adjusted so that 1 mw of added power in the thermistor will give a meter reading of 100 (center of dial). Over a limited range (up to 1 mw) the meter reading is directly proportional to the added power.

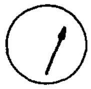
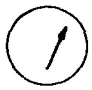
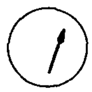
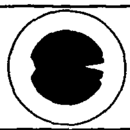
When measurements are made, the bridge is first balanced by applying the correct amount of d-c power to the thermistor; the resistance in series with the meter is then adjusted so that 1 mw of added power from the d-c supply will cause the meter to read 100. The d-c power is then reduced until the meter deflection is again zero. The r-f power to be measured is applied to the thermistor and the meter deflection again noted. One milliwatt of r-f power is equivalent to one milliwatt of d-c power and will cause the meter to read 100 divisions.

A correct impedance match between the thermistor and the waveguide in the meter is obtained so that substantially all of the r-f power will be absorbed—that is, will be converted to heat energy.

A functional block diagram of the equipment is shown in figure 7-28, A. R-f power is fed to the waveguide by means of an r-f cable adaptor.

The guillotine db input attenuator moves an energy-absorbing element (carbon-coated blade) into the waveguide. The position of the blade is calibrated on the attenuator db dial in terms of loss in decibels.

The thermistor is mounted between top and bottom faces at the center of the waveguide and parallel with the electric lines of force. The bottom end of the thermistor is grounded to the waveguide face, and the top end connects through an r-f by-pass capacitor, which consists of a plastic disc between the outside face of the waveguide and thermistor mount. The d-c power-measuring circuit is connected between this post and ground. Short-circuited coaxial stubs are in the top and bottom faces of the waveguide—one at each end of the thermistor. The bottom stub is tunable; also, the reflector plate at the end of the waveguide section can be tuned by means of a screw. The stub and reflector (in combination with the thermistor adjustment) serve to match the thermistor to the impedance of the waveguide, thus making the standing-wave ratio satisfactory.

EFFECT	APPEARANCE ON RADAR INDICATOR	APPEARANCE ON ECHO BOX METER	PROBABLE CAUSE
RINGTIME — NORMAL ECHO BOX METER — NORMAL			RADAR PERFORMANCE SATISFACTORY.
RINGTIME — LOW ECHO BOX METER — NORMAL			RECEIVING TROUBLE: DETUNED MIXER OR LOCAL OSCILLATOR, BAD CRYSTALS, EXCESSIVE I-F NOISE, ADJUSTMENT OF PROBES IN MIXER CAVITY, DETUNED T/R BOX.
RINGTIME — LOW ECHO BOX METER — VERY LOW			LOW POWER OUTPUT-CHECK SPECTRUM.
RINGTIME — LOW ECHO BOX METER — LOW			TROUBLE PROBABLY IN TRANSMITTER AND RECEIVER AND/OR TROUBLE IN TRANSMISSION LINE.
RINGTIME — ERRATIC ECHO BOX METER — STEADY			ECHO BOX DETUNED. BAD PULSING, DOUBLE MODING TRANSMITTER, OR LOCAL OSCILLATOR POWER SUPPLY TROUBLE. CHECK SPECTRUM.
RINGTIME — ERRATIC ECHO BOX METER — ERRATIC			FAULTY TRANSMISSION LINE OR CONNECTION — CONDITION WORSE WHEN LINE IS VIBRATED.
END OF RINGTIME SLOPES GRADUALLY, POSSIBLY EXCESSIVE RINGING GRASS APPEARS COARSE. ECHO BOX METER-STEADY AND SATISFACTORY.			OSCILLATING I-F STAGE
PRONOUNCED DIP IN RINGTIME AT END OF PULSE.			FAULTY T/R TUBE
RINGTIME-SLIGHTLY LOW POOR OR BAD SPECTRUM.		 POOR SPECTRUM	TRANSMITTING TROUBLE
BLANK SPACES OR ROUGH PATTERN ON PPI RINGTIME INDICATOR. ECHO BOX METER READING VARIES AS ANTENNA IS ROTATED.			FREQUENCY PULLING OF TRANSMITTER DUE TO BAD ROTATING JOINT OR TO REFLECTING OBJECT NEAR RADAR ANTENNA.

55.122

Figure 7-25.—Troubleshooting chart.

The r-f gate is used for making a check of zero balance in the bridge without disturbing the setting of the attenuator. When the r-f gate plunger in the waveguide is pushed in, nearly all the r-f power will be reflected and will not reach the thermistor.

The thermistor may be heated with power from the battery in the battery case. This is

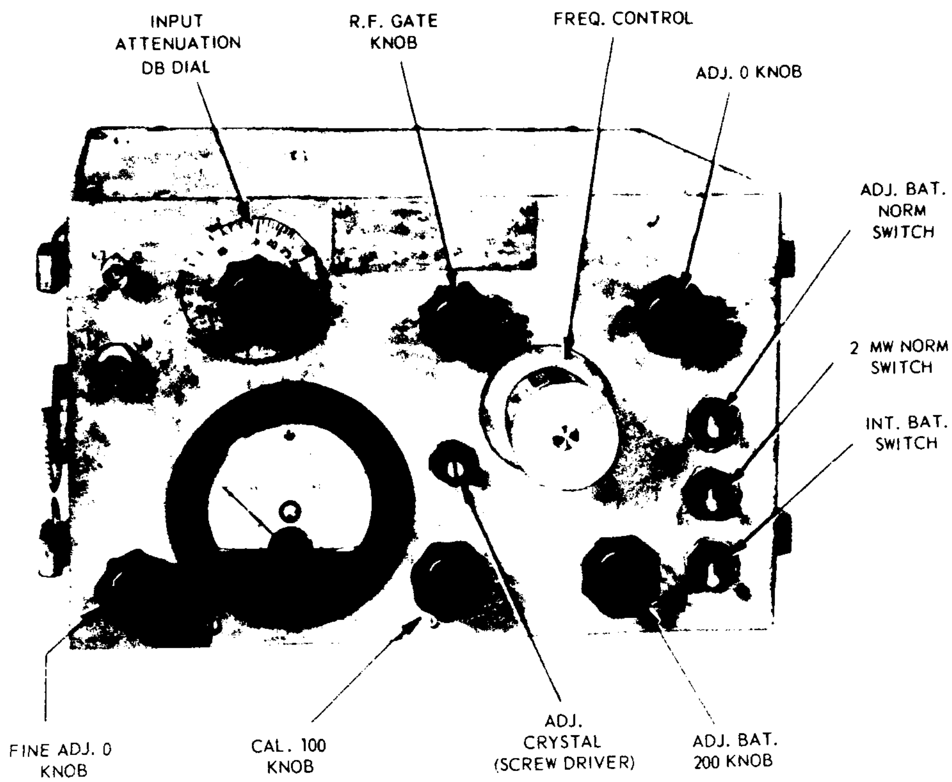


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Figure 7-26.—Front view of Frequency-Power Meter TS-230B/AP.

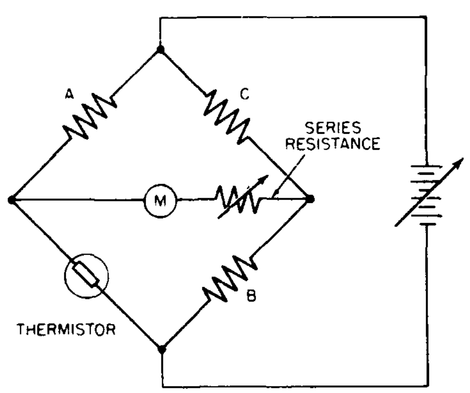

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Figure 7-27.—Thermistor bridge circuit.

the most convenient method for locations remote from external power, especially when the tests are made during a short period of time. If the internal battery is used for extended periods, its voltage decreases and frequent adjustments are needed during tests. External batteries may be connected to the external battery jack.

In order to measure power, the frequency-power meter is calibrated (as outlined in the instruction book) and the ADJ ZERO control (in the main control circuit from the battery to the bridge network) is set to the position that makes the meter read zero. The frequency-power meter is connected to the radar system; the radar transmitter is turned on and the input attenuator adjusted until a reading of 100 is obtained on microammeter, M. The input attenuator reading then represents the level in db above 1 mw at the input of the

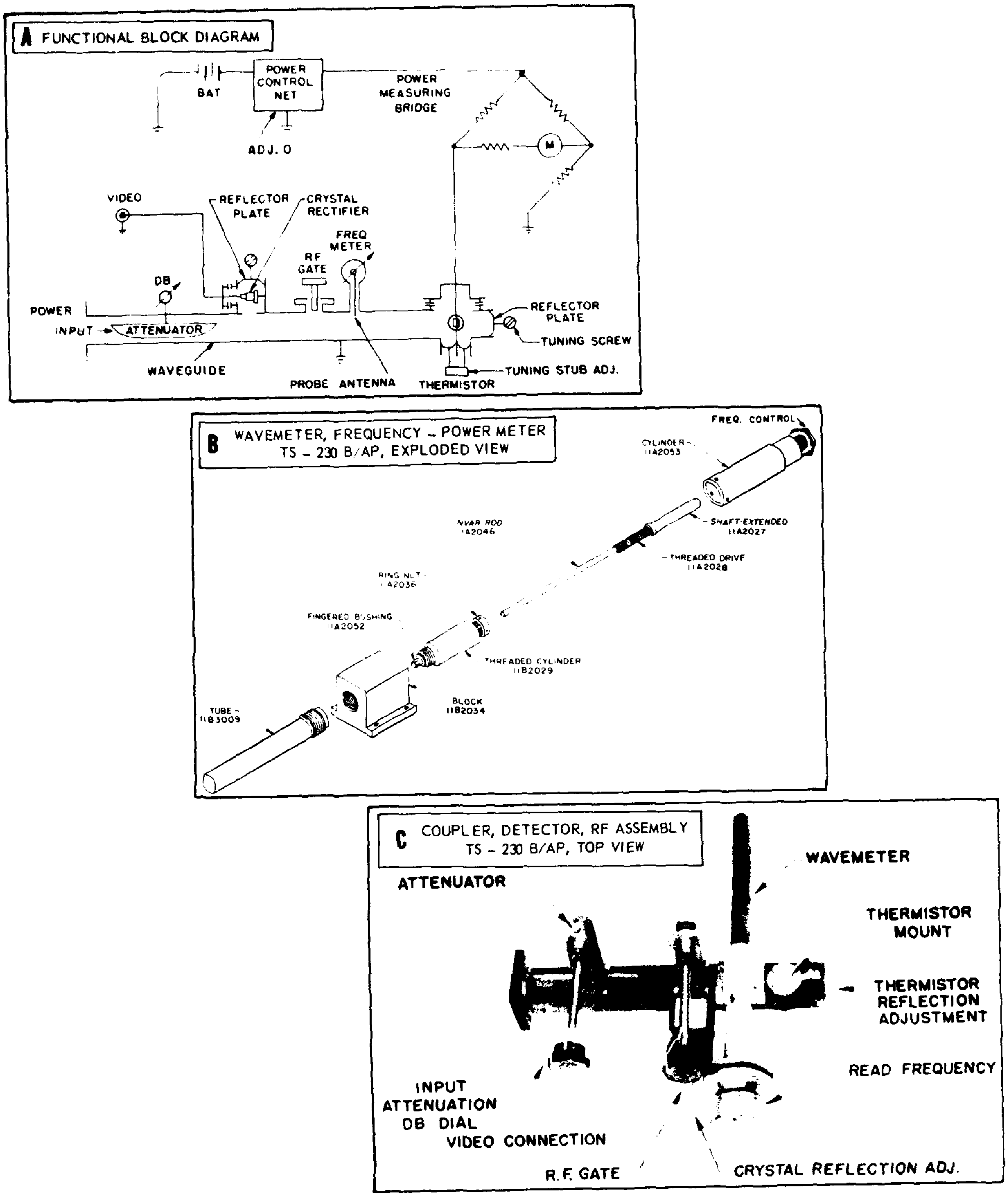

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Figure 7-28.—Functional block diagram and r-f plumbing of frequency-power meter.

waveguide. If the input attenuator dial is turned toward zero and the meter reads progressively less than 100, the meter reading will represent the power absorbed by the thermistor in hundredths of a milliwatt (one division equals 0.01 mw).

To obtain the average power output in the radar waveguide, the input attenuator reading is added to the db loss of the directional coupler (not shown in the figure) between the radar waveguide and the frequency-power meter. The loss in the directional coupler is stamped on the coupler; if a horn pickup antenna is used, the accompanying instruction book will give instructions on figuring losses. The power in watts corresponding to the total dbm (db, above 1 mw) is read directly from a table (not shown). This represents the average power of the radar output.

The meter reading indicates only the average levels of pulsed power throughout the pulse cycle. The peak power can be computed from the average power (Peak-to-Average power conversion method) if the duty cycle ratio is known. The duty cycle ratio is obtained from the radar instruction book or by assuming a rectangular pulse shape and using the following formula:

$$\text{Duty-cycle ratio} = \frac{\text{pulse length}}{\text{pulse repetition time}},$$

where pulse length is in seconds and the pulse repetition rate is given in number of pulses per second.

Representative duty-cycle ratios for radars in the band covered by this instrument are shown in table 7-1, which shows ratios in terms of decimal fractions, common fractions, and db. In table 7-1 and in the preceding formula, a perfect square-wave pulse is assumed. For this reason, duty-cycle ratios given in instruction books for particular radars may differ somewhat from these computed values. The handbook value should be used if it is available.

The peak power is obtained by dividing the average power by the duty-cycle ratio. As an example, let it be assumed that the average power of a radar transmitter, as determined by

Table 7-1.—Radar Duty Cycles.

Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio		Repetition Rate (PPS)	Pulse Length (Micro-second)	Duty Cycle Ratio	
		Decimal Fraction	Common Fraction*			Decimal Fraction	Common Fraction*
2,000	0.05	0.000100	1/10,000	600	0.25	0.00015	1/6,600
1,800	0.3	0.00054	1/1,800	600	0.5	0.00030	1/3,300
1,640	0.5	0.00082	1/1,200	480	0.75	0.00036	1/2,800
1,520	0.5	0.00076	1/1,300	400	2.25	0.00090	1/1,100
1,348	0.5	0.00067	1/1,500	400	1.00	0.00040	1/2,500
1,200	0.25	0.00030	1/3,300	400	0.5	0.00020	1/5,000
1,000	2.0	0.00200	1/500	375	2.25	0.00084	1/1,200
1,000	0.75	0.00075	1/1,300	375	1.125	0.00042	1/2,400
1,000	0.5	0.00050	1/2,000	350	2.5	0.00087	1/1,100
800	2.25	0.00180	1/600	350	2.25	0.00079	1/1,300
800	1.25	0.00100	1/1,000	270	2.25	0.00061	1/1,600
800	0.6	0.00048	1/2,100	200	5.0	0.00100	1/1,000
760	1.25	0.00095	1/100	200	4.00	0.00080	1/1,300
760	0.333	0.00025	1/4,000	200	1.00	0.00020	1/5,000
750	1.125	0.00084	1/1,200	60	20.0	0.00120	1/800
600	2.0	0.00120	1/800	60	5.0	0.00030	1/3,300
600	1.0	0.00060	1/1,600	60	1.5	0.00009	1/11,000
600	0.75	0.00045	1/2,200				

*Denominator to nearest 100.

the frequency-power meter, is 25 w. Assume also that the transmitter radiates pulses 0.5 μs long 600 times per second. The calculations are as follows:

1. The duty-cycle ratio (on a square-wave basis) is the product of the pulse length in microseconds and the repetition rate in pulses per second divided by 10^6. That is,

$$\text{duty-cycle ratio} = \frac{0.5 \times 600}{10^6} = 3 \times 10^4.$$

2. The peak power is equal to the average power divided by the duty-cycle ratio, or

$$\text{peak power} = \frac{25}{3 \times 10^4} = 83{,}000 \text{ w.}$$

RADAR TEST SET AN/UPM-56

In general, radar test sets will perform more functions than frequency-power meters. For example, Radar Test Set AN/UPM-56 (fig. 7-29) is a portable microwave signal generator, power meter, and frequency meter; in addition, many allied functions can be performed. In this portion of the chapter we are concerned principally with its use as a power meter.

This test set can make r-f power measurements of pulsed or c-w power in the frequency range of 8500 to 9600 mc/s. The range of power that can be measured directly is from +1 to +30 dbm average (1 mw to 1000 mw). Power in excess of +30 dbm average can be measured by using an external attenuator. Power down to -9 dbm (0.126 mw) can be measured on the bridge meter, but this measurement is somewhat less accurate. Power measurements are made by attenuating the unknown power down to a reference level of 1 mw The amount of attenuation is then read on a calibrated dial. The 1-mw reference is established in a thermistor bridge circuit.

The attenuators in the test set consist of waveguide sections within which are glass strips coated with a resistive material such as carbon, which absorbs r-f energy. These

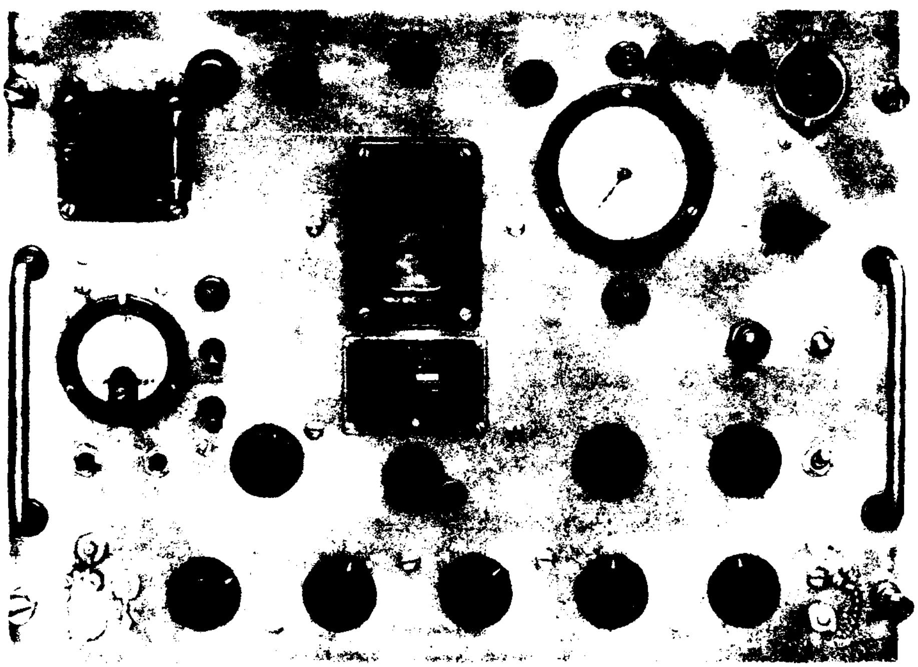

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Figure 7-29.—Front view of Radar Test Set AN/UPM-56.

attenuators are shown in the simplified phantom view of the r-f plumbing in figure 7-30. The glass strips run lengthwise in the waveguide. One of the attenuators, AT103 (calibrated attenuator) is continuously variable and has a 1 to 30 dbm calibrated range. It is the r-f level control on the panel of the test set. Attenuators AT101 and AT102 are of the step type, each having a 0-db position and a 35-db position. The step attenuators are controlled from the same knob (R-F LEVEL SELECTOR), which also controls the r-f cutoff in the T-section that connects the klystron oscillator mount to the waveguide and the T-section attenuator.

When the power of external signals is being measured AT101 and AT102 are in the 0-db position (r-f in on the r-f level selector (fig. 7-29)), the klystron oscillator is shut off, and the T-section attenuator is in a position of minimum attenuation. The calibrated r-f level control is used for adjusting attenuation. The lowest attenuation of the r-f level control is 1 dbm; this results from the attenuation inherent in the waveguide, from the attenuators in the zero position, and from other waveguide losses.

A simplified schematic diagram of the thermistor bridge wattmeter is shown in figure 7-31 A; the bead thermistor is illustrated in part B.

A bead thermistor is a temperature-sensitive device whose resistance decreases with an increase in temperature. There are three causes of temperature variations that affect the resistance of the bead thermistor—the ambient temperature (surrounding temperature), the heating effect due to an applied voltage, and the heating effect due to an applied r-f field.

The thermistor bridge wattmeter contains two bridge circuits; one is a control bridge, and the other a power-measuring bridge. The control bridge provides a means of compensating for ambient temperature changes that would normally affect the calibration of the

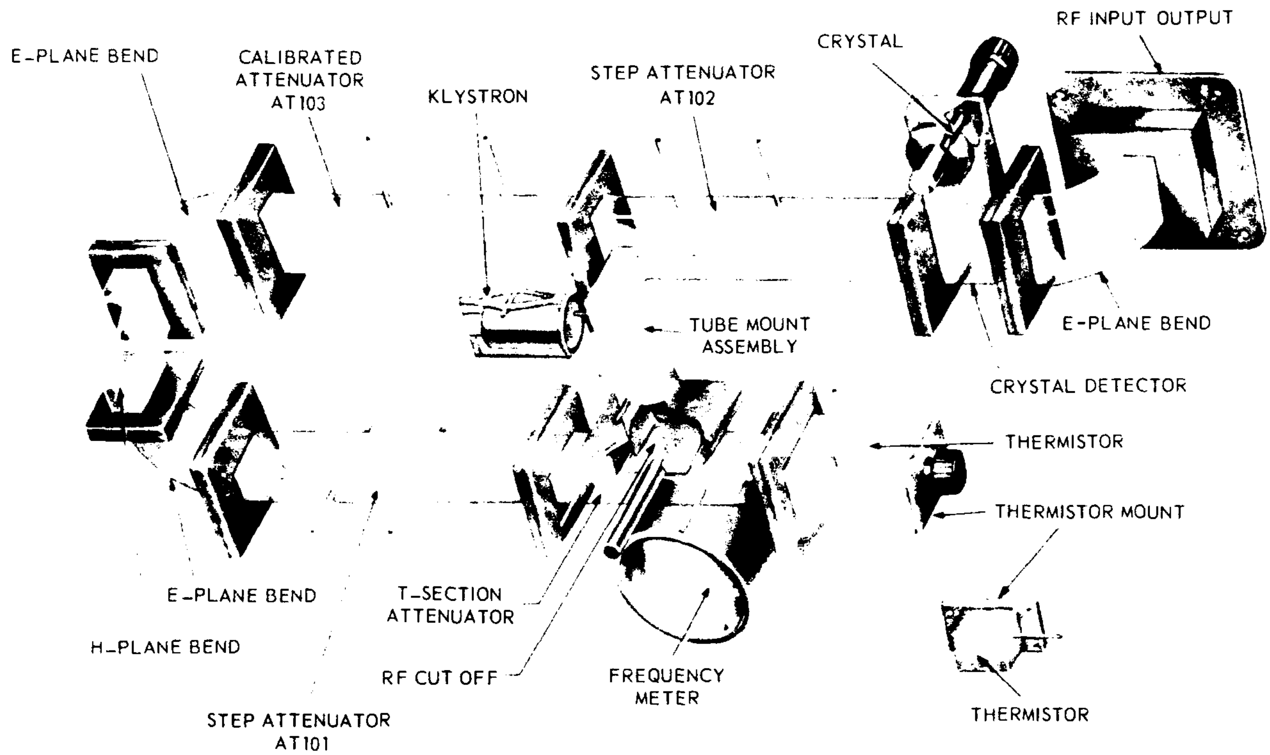

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Figure 7-30.—Simplified phantom view of r-f plumbing.

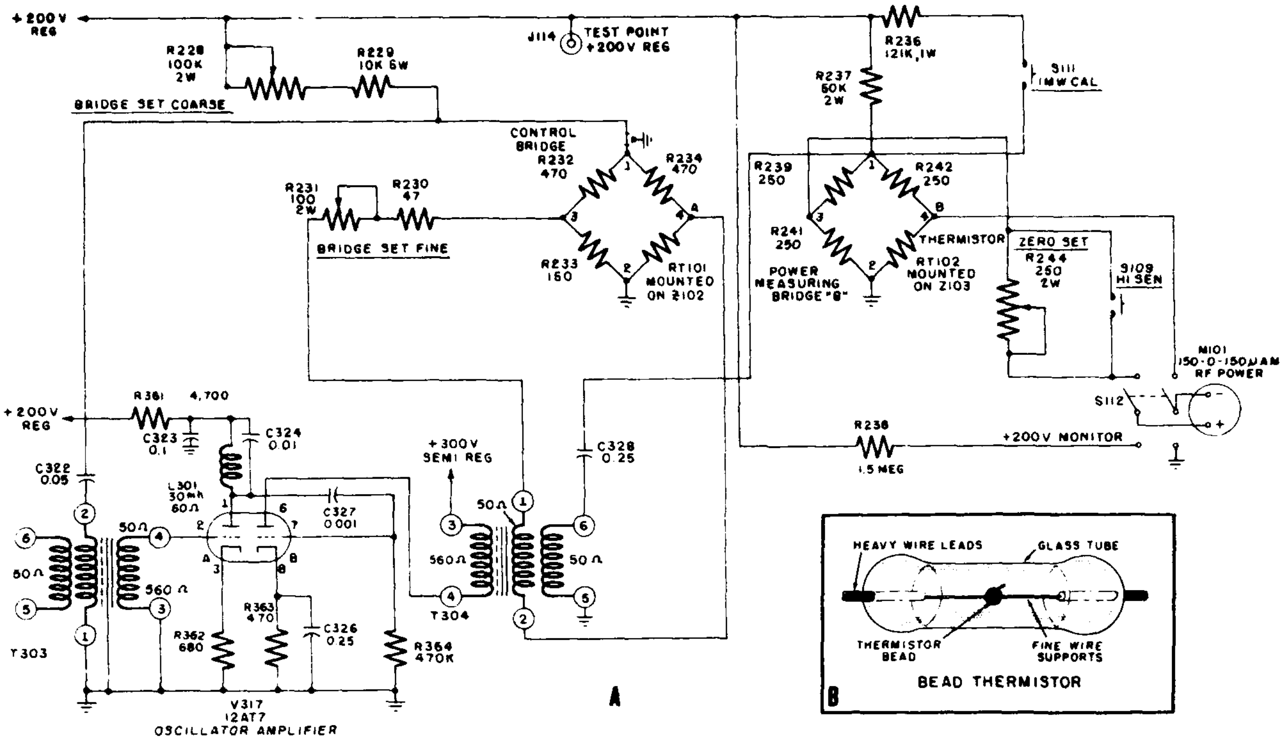

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Figure 7-31.—Simplified schematic diagram of the thermistor bridge wattmeter.

power-measuring bridge. The control bridge employs thermistor RT101 in one arm to balance a 150-ohm resistor, R233, in another arm. The remaining two arms contain 470-ohm resistors (R232 and R234).

The power-measuring bridge consists basically of bead thermistor RT102 and resistors R239, R241, and R242. Bead thermistor RT102 is mounted in waveguide section Z103 (fig. 7-30) where r-f power is applied to it from the r-f input/output connector. The resistance of thermistor RT102 at room temperature is higher than that of resistors, R239, R241, and R242, each having a resistance of 250 ohms.

The object is to obtain bridge balance (all four resistances equal) when 1 mw of r-f power is applied to thermistor RT102. In order to do this, two voltages are applied simultaneously across terminals 1-2 of the power-measuring bridge.

One voltage is a regulated +200 volts d-c applied through R237. This voltage accomplishes two purposes: first, it supplies the d-c voltage that causes the bridge meter to indicate balance or degree of unbalance; and, secondly, it reduces the resistance of thermistor RT102 by dissipating heat in it.

The other voltage is a variable a-c voltage of about 10 kc. This voltage also accomplishes two purposes: first, it dissipates heat in RT102 in varying amounts to compensate for changes in ambient temperature; and, secondly, it allows for the initial setting of the bridge. This voltage is obtained from the 10-kc oscillator, V317. The oscillator output voltage is regulated by the control bridge.

Another d-c voltage is applied to the power-measuring bridge when the 1-mw calibrated pushbutton switch, S111 is closed. This voltage exactly corresponds in temperature effect to the application of 1 mw of r-f power to RT102.

Before r-f power is applied to RT102, the BRIDGE SET FINE control, R231, is positioned (with S111 closed) so that meter M101 reads SET POWER (1-mw level). Switch S111 is then released and the ZERO SET control, R244,

adjusted until the meter indicates SET ZERO (0 mw). The BRIDGE SET FINE control, R231, is again positioned (with S111 closed) so that the meter reads SET POWER (1-mw level). Switch S111 is then released again.

When 1 mw of the r-f power being measured is applied to thermistor RT102, the meter again reads SET POWER (1 mw).

The output of the oscillator-amplifier is fed through T304 to both the control bridge and the power-measuring bridge. A regulated direct voltage is applied to terminals 1-2 of the control bridge through the BRIDGE SET COURSE control and R229. The 10-kc output from T304 is applied to terminals 3-4. The amount of a-c voltage appearing across terminals 1-2 depends on the resistance of bead thermistor RT101. This voltage is applied through C322 to input transformer T303. This is the feedback loop for the oscillator. For an initial setting, the amount of feedback is determined by the resistance of thermistor RT101 and the amount of voltage applied from the output winding of T304, as controlled by the BRIDGE SET FINE adjustment.

After the initial setting, any changes in ambient temperature are reflected in resistance changes in thermistor RT101, in feedback, and in oscillator-amplifier output to the power-measuring bridge. Thus, changes in ambient temperature that normally would cause power-measuring thermistor RT102 to change resistance are compensated by adding or subtracting heat effects caused by the alternating voltage applied to its bridge. The following example will illustrate the principles of POWER MEASUREMENT. Assume that a certain radar transmitter with a built-in directional coupler having a 20-db attenuation is connected to the test set with an r-f cable having a 3.5 db loss.

The test set power-measuring bridge is first properly calibrated. When r-f power is applied, the dbm dial reads 17.5 dbm when the bridge R-F power meter indicates 1 mw. The total db attenuation with reference to 1 mw is 20 db + 3.5 db + 17.5 db = 41 dbm (1-mw reference).

The average power output of the radar transmitter in watts is 41 db above 1 mw. From the dbm-to-watts conversion chart (fig. 7-32), the corresponding average power output of the radar system in watts is approximately 12.5 w.

The peak power is equal to the average power divided by the duty-cycle ratio. The duty-cycle ratio (for a square wave) is equal to the product of the pulse length in microseconds and the pulse repetition rate, PRF, in pulses per second, divided by 10. Expressed as a formula, the peak power is

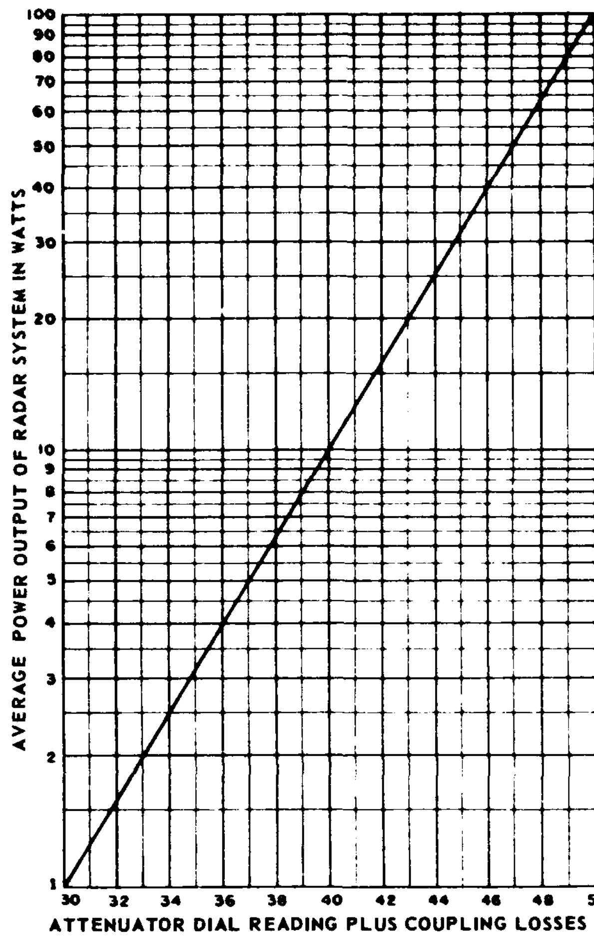

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Figure 7-32.—Dbm-to-watts conversion chart.

$$\text{peak power} = \frac{\text{average power}}{\text{duty-cycle ratio}} =$$

$$\frac{\text{average power}}{\text{pulse length x (PRF)}} =$$

$$\frac{\text{average power x } 10^6}{\text{pulse length x (PRF)}},$$

where the peak power and the average power are in watts.

If the pulse length is 0.8 μs, the pulse repetition rate is 1706 pulses per second, and the average power is 12.5 w, the peak power will be

$$\text{peak power} = \frac{12.5 \times 10^6}{0.8 \times 1706} = 9150 \text{ w. (approx).}$$

A chart for converting average power to peak power is illustrated in figure 7-33. From this chart the db value is indicated for the example being considered as 28.65 db at point C. From this value the peak power is found from the formula,

$$\text{db} = 10 \log \frac{\text{peak power}}{\text{average power}}$$

$$28.65 = 10 \log \frac{\text{peak power}}{\text{average power}}$$

$$\frac{\text{peak power}}{\text{average power}} = 733$$

$$\text{peak power} = 733 \times 12.5 = 9150 \text{ w. (approx)}$$

RADAR TEST SET AN/UPM-99

The Radar Test Set AN/UPM-99 (fig. 7-34) consists of Radar Test Set TS-1253/UP, coder simulator SM-189/UPM-99, and power supply PP-2391/UPM-99. A variety of minor components have been designed to augment the utility of the test sets. Figure 7-35 is a simplified block diagram of Radar Test Set AN/UPM-99.

The Radar Test Set TS-1253/UP contains four modularized plug-in units; the Xtal Mark and Sync, Sweep and Inten Mark, Display, and SIF Coder units. D-c plate, bias, and a-c filament power are supplied by a power supply in the main chassis.

The pulse generator circuits of the Xtal Mark and Sync unit operate from external positive or negative, or externally generated trigger pulses. Positive suppressor, zero delay "0", and delay trigger outputs are supplied at panel connectors. The delayed trigger pulse is also provided at the input power connector of the unit for triggering the Mark X Coder in the SM-189/UPM-99, and for use within the TS-1253/UP. Internal connections supply output triggers from this unit to the Sweep and Inten Mark unit. Internal connections also supply

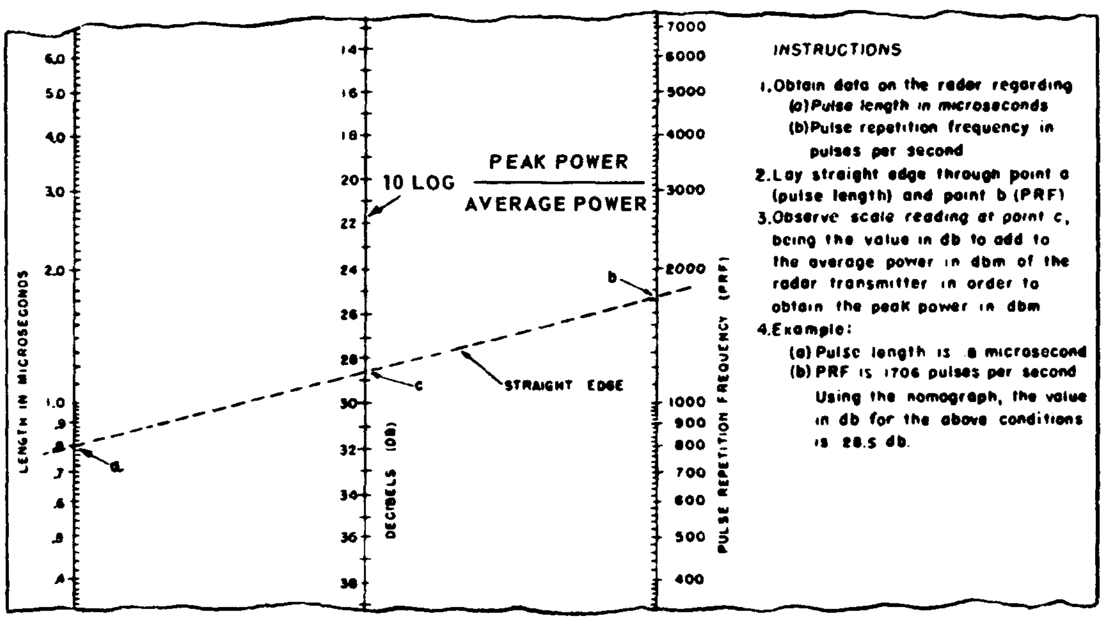

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Figure 7-33.—Average-to-peak power conversion chart.

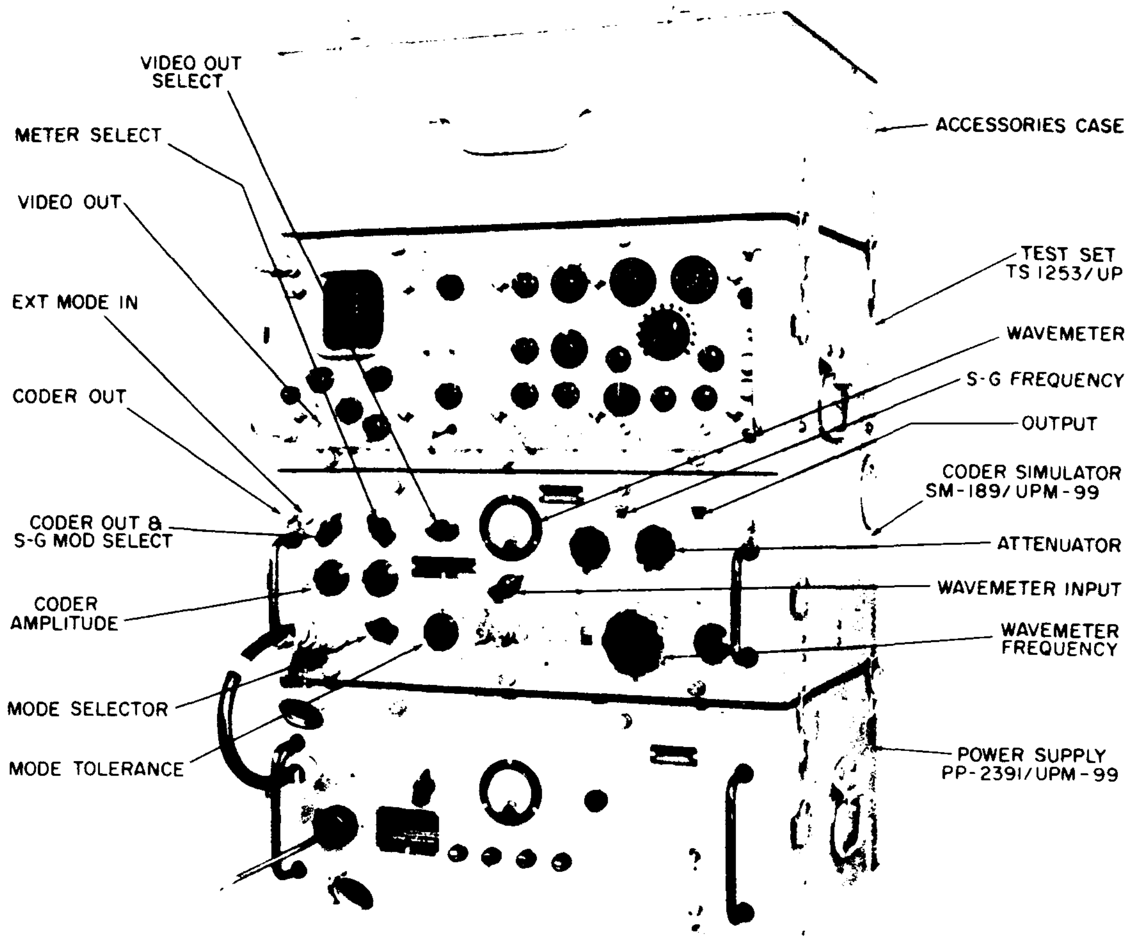

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Figure 7-34.—Radar Test Set AN/UPM-99, unit location and interconnection.

video marker output from the Xtal Mark and Sync unit to the Display unit, providing an accurate time calibration on the display sweep.

The Sweep and Inten Mark unit contains the triggered sweep generator and an intensity marker generator. Horizontal sweep output is supplied to the cathode-ray tube of the Display unit. Intensity marker output is also supplied to the cathode-ray tube and provides time-scale marks for the different sweep durations. Appropriate trigger inputs are selected by operator controls. All connections are internal.

The Display unit contains the cathode-ray tube, r-f type high voltage supply, and a video amplifier for vertical deflection. Video markers, intensity markers, horizontal sweep voltage, and power are supplied from the other units of the test set. A panel connector is provided for video input.

The SIF Coder unit requires an external positive trigger to initiate the generation of a coded pulse train. Operator controls permit code selection and output amplitude adjustment. Continuously variable, low level output is supplied at the VARI OUTPUT panel connector. High level output is supplied at the MOD DRIVE panel connector. A two-position switch controls the relative output levels from both panel connectors. The Xtal Mark and Sync unit, or other external equipment, supplies the

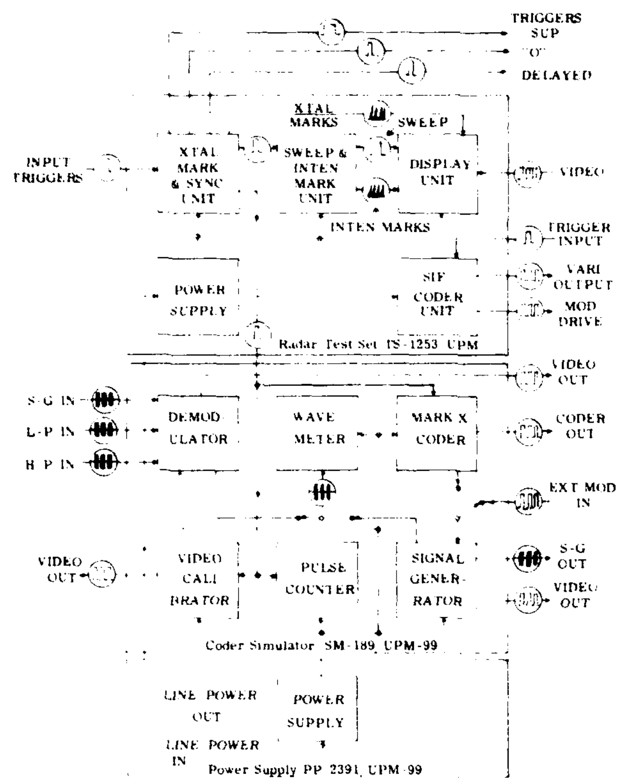

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Figure 7-35.—Radar Test Set AN/UPM-99, block diagram.

input trigger to the panel connector of the SIF Coder unit. The unit (except the power supply) is a complete coded pulse-train generator.

A drawer chassis assembly contains the power control, rectifier, and regulator circuits for Radar Test Set TS-1253/UP. It also provides mountings and interconnections for the plug-in units of the test set.

The Coder Simulator SM-189/UPM-99 component contains six sections; Mark X Coder, Pulsed R-F Signal Generator, Wavemeter, Demodulator, Pulse Counter, and Video Calibrator. These sections provide the facilities for generation of Mark X interrogations and replies, pulsed UHF signals, prf measurement, and generation of amplitude calibrated pulses.

The Mark X coder produces video pulses when internally triggered by delayed triggers from the Xtal Mark and Sync unit. These output pulses simulate the pulses used in various identification and recognition sets of the IFF system. Selection of the type of output is made by the MODE SELECTOR switch. Table 7-2 lists the types of available outputs.

To generate the six types of Mark X code pulses listed in the table, the coder circuitry can be employed in three methods of operation (fig. 7-36).

The FIRST METHOD OF OPERATION (fig. 7-36, A) generates 1-μsec wide paired Mark X challenge pulses for Modes 1, 2, and 3. The positive-polarity input trigger from the Xtal Mark and Sync unit is applied through a capacitor to the grid of trigger amplifier V301. The resulting output at the primary and secondary of T303 is a pair of identical pulses spaced approximately three, five, or eight μsec. A MODE TOLERANCE control (fig. 7-34) permits variation of approximately plus or minus one-half μsec in the pulse spacing.

In the SECOND METHOD OF OPERATION (fig. 7-36, B), a variable pulse from 0.9 to 1.3 μsec is generated to simulate a basic Mark X single pulse reply. The input trigger applied to the grid of trigger amplifier V301 causes first blocking oscillator V302 to operate. As opposed to coder operation in generating paired pulses, no delay line is connected in the grid circuit, of the first blocking oscillator. Output variation of the width of the single pulse is controlled by the MODE TOLERANCE control. When the MODE SELECTOR (fig. 7-34) is in the REPLY-SINGLE PULSE position, the maximum variation is from 0.9 to 1.3 μsec.

In the THIRD METHOD OF OPERATION (fig. 7-36, C) are generated the double and quadruple pulses Mark X replies. In this type of operation the Mark X coder produces either a pair of pulses or four pulses approximately 1 μsec each in duration with spacing between pulses variable from approximately twelve to nineteen μsec. When the MODE SELECTOR is in the REPLY-DOUBLE PULSE position the output at pulse transformer T303 consists of two identical pulses and for the REPLY-EMERGENCY position four identical pulses are produced.

The CODER OUT & S-G MOD SELECT switch (fig. 7-34) has four positions: NEG., POS., MARK X S-G MOD, and EXT S-G MOD. In the NEG. position, terminal 1 of output pulse transformer T303 is grounded and an output of negative polarity is applied to the CODER OUT connector on the front panel of the Coder Simulator SM-189/UPM-99. In the POS. position, terminal 6 of T303 is grounded

Table 7-2.—Mark X Coder Output Pulse Types.

Mode Selector Switch Position	Type Of Output	Pulse Duration (Microseconds)	Pulse Spacing (Microseconds)
CHALLENGE-MODE 1	Paired	1.0 nominal	2.5 to 3.5
CHALLENGE-MODE 2	Paired	1.0 nominal	4.5 to 5.5
CHALLENGE-MODE 3	Paired	1.0 nominal	7.5 to 8.5
REPLY-SINGLE PULSE	Single	0.9 to 1.3	- - -
REPLY-DOUBLE PULSE	Paired	1.0 nominal	12.5 to 19.5
REPLY-EMERGENCY	Quadruple	1.0 nominal	12.5 to 19.5

and an output of positive polarity is applied to the CODER OUT. In both of these cases, the Mark X coder output amplitude may be varied by operating the CODER AMPLITUDE control.

When the CODER OUT & S-G MOD SELECT switch is in the MARK X S-G MOD position, transformer T303 is disconnected from the CODER OUT connector. Terminal 1 of T303 is connected to the cathode circuit of a modulator drive stage, and terminal 6 remains grounded. The CODER AMPLITUDE control is inoperative in this case.

In the EXT position, terminal 1 of T303 is disconnected from the CODER OUT connector, and the EXT MODE IN connector is connected to the cathode circuit of the modulator driver stage.

The RF Signal Generator has a continuous tuning range from 925 to 1225 mc. Calibration charts are provided that can be read to within 5 mc. When greater accuracy (up to 0.2 mc) is required, the wavemeter is used to check generator frequency. The RF signal generator consists of an oscillator, and automatic level control (ALC) system, a modulator, and a variable attenuator.

The output level can be read directly from the OUTPUT dial on the front panel and may be varied by the attenuator from 21 to 121 db below one volt rms (equivalent to 89,100 to 0.891 v) when terminated by a 53.5 ohm load. Modulation pulses are supplied by the coder to a modulator circuit. The pulsed RF output simulates the challenge and reply pulses of the equipments comprising the Mark X IFF system and equipments comprising the SIF systems. A substantially constant output reference level is maintained over the entire frequency range by means of the automatic level control system.

The Wavemeter serves to measure the frequency of pulses RF power sources and covers a range of from 925 to 1225 mc. It is necessary to use the wavemeter to determine accurately the frequency of the RF oscillator. This is done when the WAVEMETER INPUT coaxial switch is held in the SIGNAL GENERATOR position. In the DEMOD. position, the wavemeter is connected to the demodulator and the wavemeter takes a small portion of the RF power input for frequency measurement. The accuracy of the wavemeter is plus or minus 0.7 mc when measuring the frequency of the RF oscillator or external sources of 0.5 to 35 peak watts when applied to the L-P IN connector, or 35 to 3500 peak watts when applied to the H-P IN connector. Calibration charts are furnished which may be read to approximately 0.1 mc. Resonance is shown by a dip on the front panel indicating meter.

The Demodulator consists of a diode operating over the frequency range from 950 to 1215 mc and producing an output: (1) without appreciable distortion for wave-shape measurement, and (2) of peak voltages for power measurements. A small portion of the power applied to the demodulator from an external equipment is applied to the input of the wavemeter so that frequency measurements can be made. Attenuated output of the RF signal generator is available at L-P IN and H-P IN so that external equipment can be challenged or triggered.

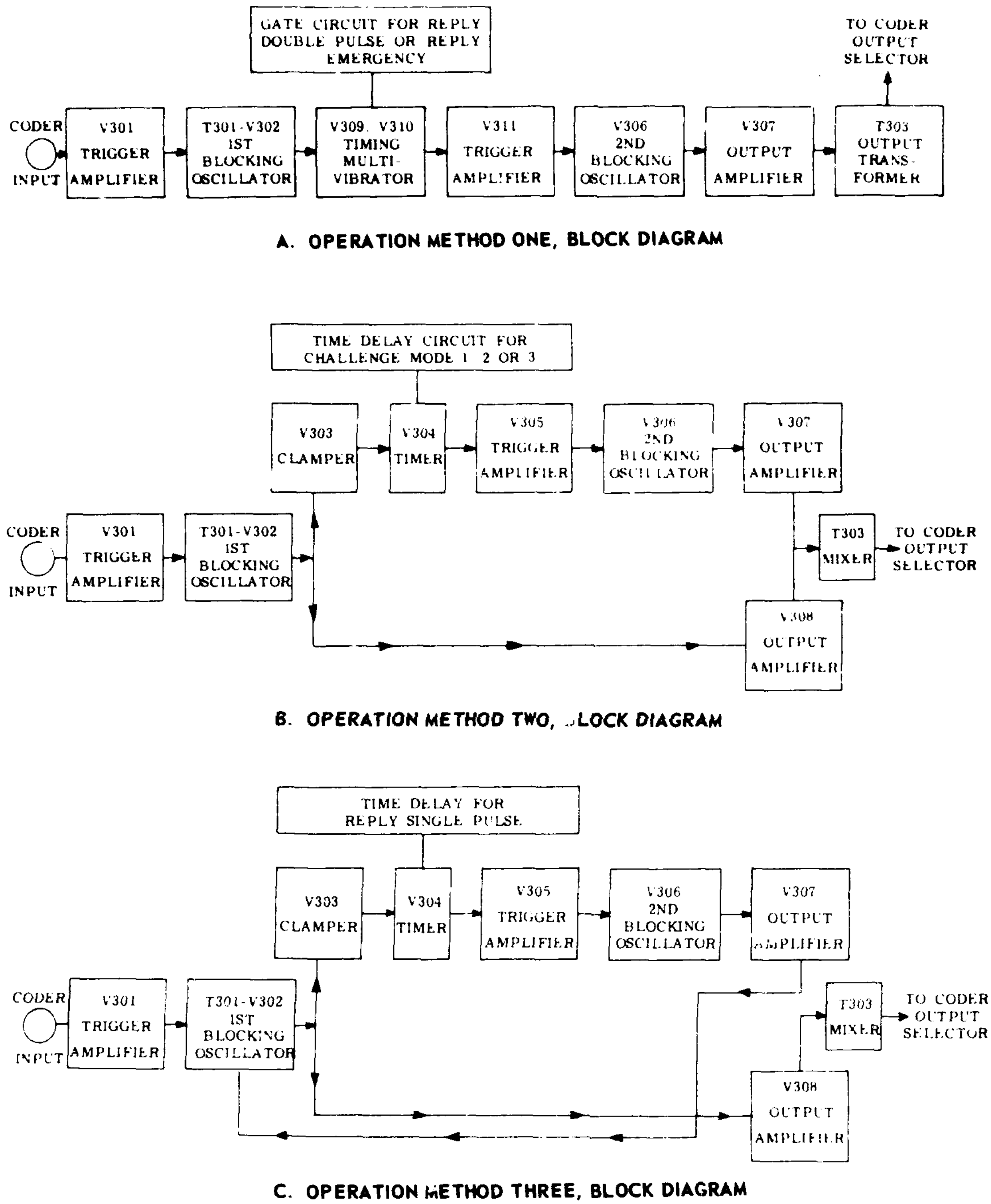

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Figure 7-36.—Three methods of operation to generate Mark X code.

The Pulse Counter counts trigger pulses produced by the blocking oscillator V302 of the Mark X Coder. It reads the pulse recurrence frequency at which the AN/UPM-99 is operating whether self-synchronized or triggered by external pulses applied at the INPUT TRIGGERS

connector (SYNC SELECT in the EXT - or EXT + position). Meter indication is given on the front panel of Coder Simulator SM-189/UPM-99; two meter scales are provided: 0 to 500 and 0 to 5000 pps.

The video Calibration unit supplies output pulses of known amplitude at the VIDEO OUT connector. One of the uses of the video calibrator is to calibrate the synchroscope in the TS-1253/UP. The output is developed across a voltage divider consisting of precision type resistors so that pulse amplitudes of 1, 2, 5, or 10 volts are available. Provision is made for self-calibration by using the front panel meter. It is possible to get video output voltages other than 1, 2, 5, or 10 volts by the setting of the CAL PULSE ADJ control. For example, if 2.5 volts are desired, the meter can be adjusted by CAL PULSE ADJ. to half scale deflection so that only 5 volts will be developed across the precision resistor voltage divider. Then if the VIDEO OUT SELECT control is set at 5, there will be 2.5 volts across that part of the divider connected to the 5 volt position.

The Power Supply is of conventional design. A time delay protection circuit is included, along with provisions for B+, bias, and filament voltages, a d-c relay supply, and a low-high input line compensation transformer network.

RADAR PERFORMANCE FIGURE

Although ringtime measurements are valuable in indicating the overall performance of a radar system, they are not as precise as Radar Performance Figure (RPF) measurements. However, neither of these measurements indicates much about how efficient the waveguide or antenna is in performing its function. Ringtime measurements are relatively easy to make; RPF measurements are more difficult to make.

The maximum range of a radar system depends on several factors—for example, (a) transmiter power, (b) receiver sensitivity, (c) the performance of the waveguide and antenna, (d) the effectiveness of the target in reflecting radar energy, and (e) atmospheric conditions.

The first two of the factors listed are especially significant in so far as equipment performance is concerned and are used in determining the RPF of a radar system. The RPF of a radar system is the ratio of the peak (pulse) power, P_p of the radar transmitter to the power of the minimum discernible signal (P_{mds}), expressed in decibels (db) or in decibels with a reference of 1 mw (that is, dbm). Expressed mathematically,

$$\text{RPF (db)} = 10 \log \frac{P_p}{P_{mds}}.$$

Because P_{mds} is a very small fraction, its log has a negative sign, and therefore

$$\text{RPF (db)} = 10 \left[\log P_p - (-\log P_{mds}\right]$$

$$\text{RPF (db)} = 10 \log P_p + 10 \log P_{mds}$$

If the power reference is 1 mw, the equation becomes

$$\text{RPF (dbm)} = P_p \text{ (dbm)} + P_{mds} \text{ (dbm)}.$$

To determine the RPF of a radar system it is necessary first to determine the transmitter average power by means of a power meter (previously discussed) and to convert the average power in dbm to peak power in dbm. The various losses must be taken into consideration in determining the power output. It is also necessary to determine the power of the minimum discernible signal.

The measurement of the minimum discernible signal (MDS) in dbm involves the use of a signal generator and an oscilloscope. The exact method of making the measurement depends on the radar set being tested. For example, the procedure for making MDS measurements on Radar Set AN/SPS-10 is given in the Maintenance Standards Book for the AN/SPS-6.

An external pulse-modulated signal and a method of viewing this signal is required. These requirements are satisfied by the use of Signal Generator TS-419/U and Oscilloscope OS-8B/U or equivalents. The test equipment is connected as shown in figure 7-37 and the correct procedures are as follows:

1. Deenergize the radar equipment (depress S102) and apply power to the signal generator and the oscilloscope.
2. Adjust the signal generator to the assigned transmitter frequency, set the FUNCTION switch to ZERO SET and adjust the ZERO SET control until the meter indication is zero.
3. Set the FUNCTION switch to CW and adjust the POWER SET control until the meter pointer is at the power set marker.
4. Set the FUNCTION SELECTOR switch to the RATE x 10 position, the PULSE WIDTH control to 2 and the PULSE RATE control to 30.

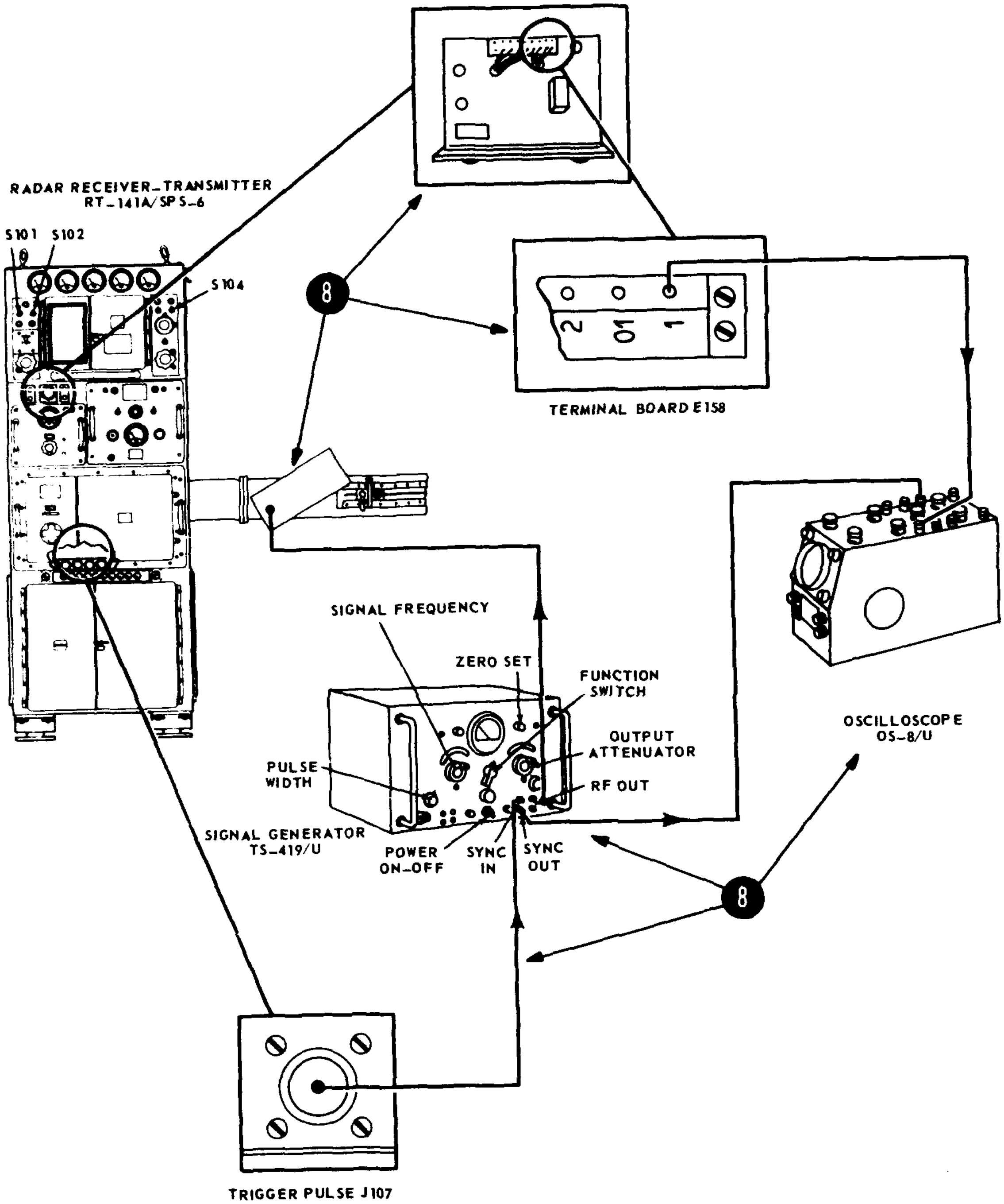

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Figure 7-37.—Test setup for making MDS measurements.

5. Make certain that all connections to the test equipment are correct, and that the oscilloscope is adjusted for maximum clarity of presentation.

6. Depress MAIN POWER ON switch (S101) on the radar set, and set MANUAL-AFC switch to MANUAL. The RADIATION switch (S104) is OFF.

7. While observing the pulse-modulated signal on the oscilloscope, slowly decrease the output of the signal generator with the OUTPUT ATTENUATOR control until the signal is barely visible in the "grass" on the oscilloscope. Read the indication on the attenuator dial in dbm.

The minimum discernible signal is the sum of the test set reading in dbm, the cable attenuation in db, and the waveguide connector in dbm. For this equipment, the power of the MDS is normally between 100 and 115 dbm.

Thus, if the peak power (Pp) output is assumed to be 90 dbm and the power of the MDS (that is P mds) assumed to be 105 dbm, the radar performance figure (RPF) is

RPF (dbm) = Pp (dbm) + Pmds (dbm)
RPF (dbm) = 90 + 105 = 195.

A graph showing the percentage loss in maximum radar range for various db losses in RPF and for various percentages of loss in ringtime is shown in figure 7-38.

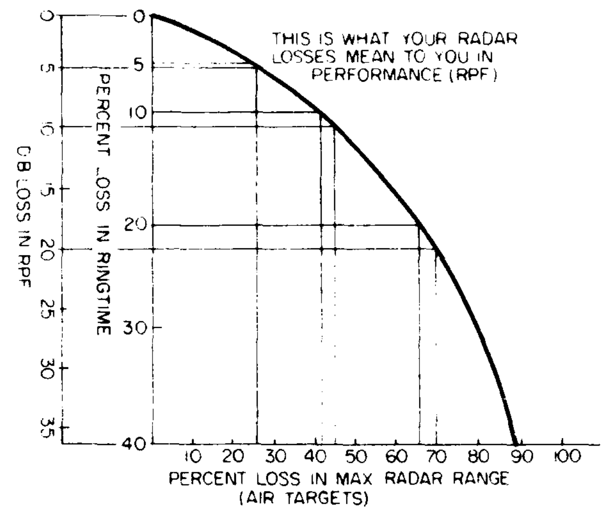

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Figure 7-38.—Effects of loss in RPF and ringtime on radar range.

CHAPTER 8

SWITCHES, SWITCHBOARDS, AND SWITCHING SYSTEMS

A basic understanding of switches and the functional use of switchboards and switching systems is a necessity for the Electronics Technician. In some instances, the switching systems used with electronic equipment are more difficult to understand than the operation of the equipment itself. In general, however, although switching systems are becoming more complex, the methods of operation are being simplified.

The Navy uses hundreds of different types of switches in (and associated with) electronic equipment. They are listed in the Federal Supply Catalog in group 59, class 30.

Switchboards make use of multisection switches that are not difficult in themselves to understand, but the entire switching function performed by switchboards, or by combinations of switchboards, may be somewhat involved. In this chapter a typical receiver switchboard and a typical transmitter switchboard are treated.

Simplified diagrams, showing how switchboards are connected to receivers, transmitters, radiophone units, and accessory equipment, are included. For completeness, block diagrams of the switching circuits between Radio Central, Radio II, and Radio III in one type of installation, are also included.

Another portion of the chapter includes a brief treatment of antenna switching systems.

Finally, the more complex radar data switching system is described with the aid of block diagrams and simplified switching circuits.

Bear in mind that in many of the switching systems described there are a large number of possible circuit arrangements. In this chapter a great deal of simplification is employed; and, in general, only the less complex arrangements are included. Enough basic information is included however, to give the prospective ET 3 the necessary background for further study in the subject.

TYPES OF SWITCHES

Some of the more common types of switches used with electronic equipment are illustrated and described briefly in this portion of the chapter. There are many variations of each type of switch; however, only a few representative examples are included here.

TOGGLE SWITCHES

Representative examples of toggle switches are shown in figure 8-1. In part A is shown a single-pole, single-throw (SPST) toggle switch, rated at 20 v and 20 amperes, and having 2 solder terminals. The schematic diagram is shown beneath the switch. This switch is used to open or close an electric circuit.

Part B shows a single-pole, double-throw (SPDT) switch, rated at 250 v and 1 ampere, and having 4 screw terminals. One of the uses of this switch is to turn a circuit on at one place and to turn it off at another place. It is sometimes called a 3-way switch.

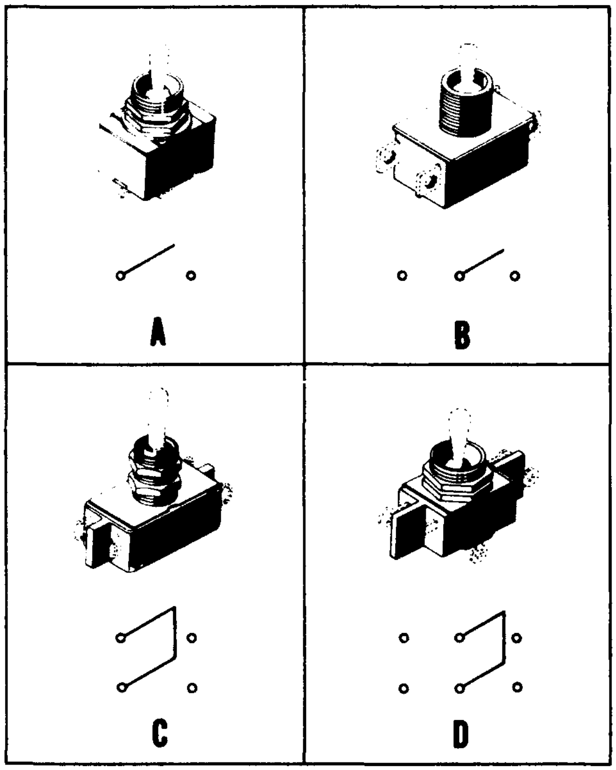
A double-pole, single-throw (DPST) switch is shown in part C. It has 4 solder terminals and is rated at 250 v and 1 ampere.

A double-pole, double-throw (DPDT) switch is shown in part D. It has 6 solder terminals and is rated at 125 v and 3 amperes.

The following types of switches are also used: 3-pole, single-throw (3PST); 3-pole, double-throw (3PDT); 4-pole, single-throw (4PST); and 4-pole, double-throw (4PDT). The voltage ratings range from 20 v to 600 v, and the amperage ratings range from 1 ampere to 30 amperes.

PUSH SWITCHES

The contact arrangement of push switches is shown in figure 8-2A, and an example of



1.98

Figure 8-1.—Toggle switches.

a typical contact arrangement is shown in part B. The type and quantity of each basic form used to make up the contact assembly are determined from part A. Part B illustrates how the illustrations in part A may be used in a practical switch assembly. Thus, in part B the switch contains a total of three separate basic forms: two forms A, and one form C. The contact arrangement for this switch is therefore 2A1C. Obviously, there are many possible contact arrangements. For example, 1A, 1A1A, 1A1B, 2A, 2A1B, 1B, etc., are common.

A push switch employing a 2A contact arrangement is shown in figure 8-2, C. It is rated at 250 v and 3 amperes.

WAFER LEVER SWITCHES

A wafer lever switch is shown in figure 8-3. It is a double-pole, triple-throw (DP3T) type of switch rated at 110 v and 0.150 ampere. It locks in position and is nonshorting; that is, one circuit is opened before the next circuit is closed. In switches of this type the action may be locking or momentary, and the contacts may be shorting (for example, one circuit remains closed until an instant after the next circuit is closed; then it is opened) or nonshorting. Other contact arrangements are DPDT, 4PDT, and 6P3T.

LEVER PILEUP SWITCHES

One type of 2-position lever pileup switch is shown in figure 8-4,A. There are 9 solder terminals, and the switch is rated at 48 v and 1 ampere. In the schematic diagrams the downstroke of the switch is designated by 2, the upstroke by 1, and OFF position by zero. The No. 2 position is momentary.

A 3-position, 21-terminal switch is shown in part B, and a 2-position, 9-terminal switch is shown in part C.

Nearly a hundred types of lever pileup switches are available for various uses. They may have up to 75 terminals, and the associated switch contacts may be arranged in various ways.

In addition to lever pileup switches, rotary pileup switches (activated by a rotary motion) and the jacktype pileup switches (activated by the thrust of the plug) are used in automatic telephone systems.

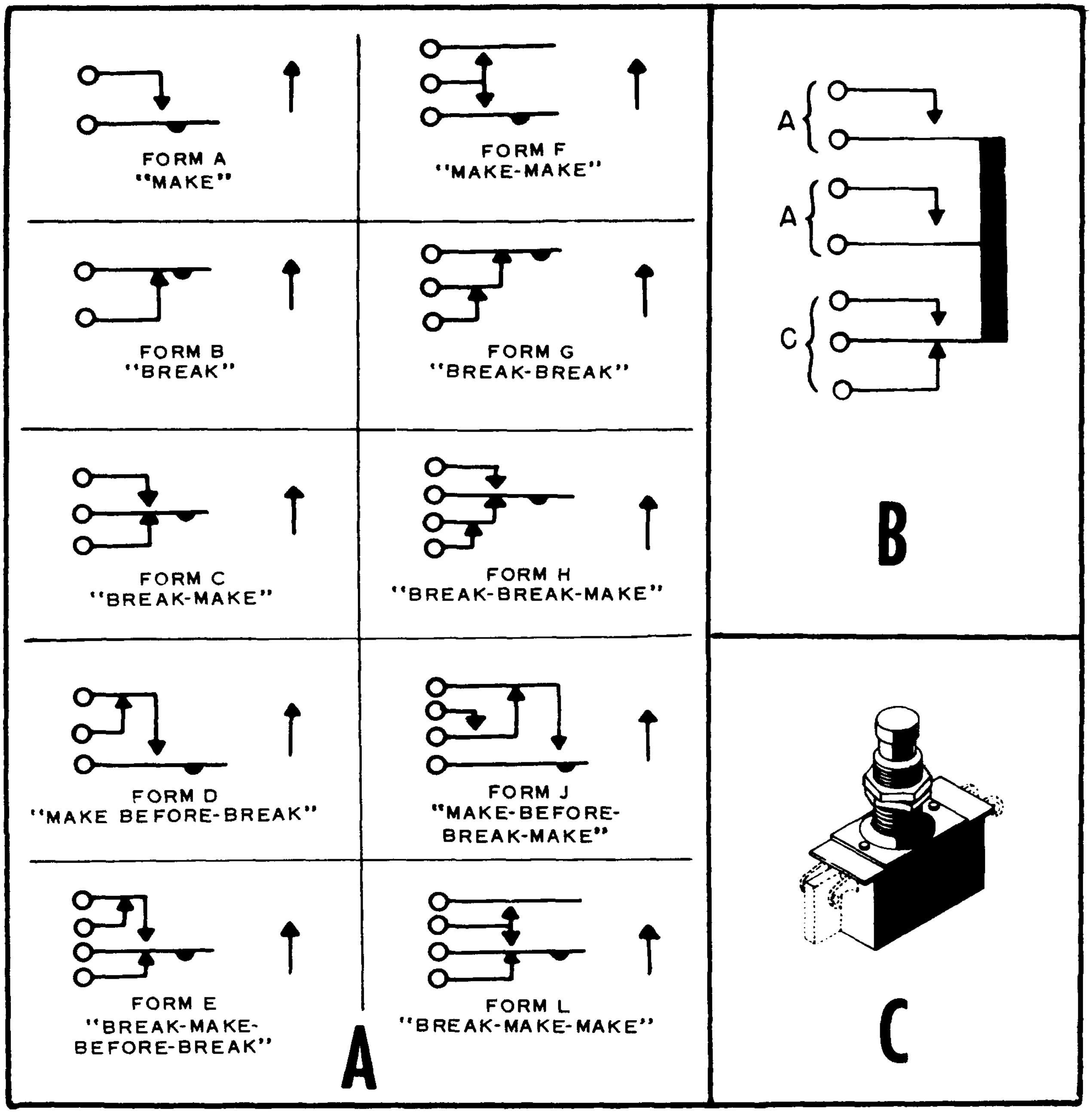
KNIFE SWITCHES

Knife switches are essentially power switches; they will handle up to 500 amperes and up to 15,000 v. Figure 8-5, A, shows a double-pole, single-throw (DPST) knife switch rated at 125 v and 30 amperes.

Part B shows a 4-pole, double-throw (4PDT) knife switch rated at 125 v and 100 amperes.

THERMOSTATIC SWITCHES

Thermostatic switches are designed to either open or close when the temperature reaches a certain value. A large number of different types of thermostatic switches are used by the Navy to control the temperatures in compartments and rooms, to regulate dampers, to maintain constant crystal temperatures in some radio transmitters; they are also used in many other heating and cooling applications. Switches of a given type may have different contact arrangements, be operated at different temperature ranges, or have different voltage or current ratings.



1.99

Figure 8-2.—Push switches.

A large number of thermostatic switches employ a bimetallic strip as the active element. The basic operating principle is illustrated in figure 8-6,A. One side of the bimetallic strip is brass and the other side is iron (other metals may also be used) welded to the brass. When the strip is heated, the brass expands more than the iron and the strip bends downward to open the switch contacts. Thus, power is removed from the load when a certain temperature is reached. The switch action may be reversed so that power is applied to the

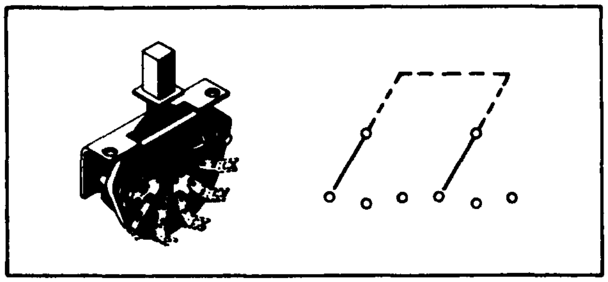


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Figure 8-3.—Wafer lever switches.

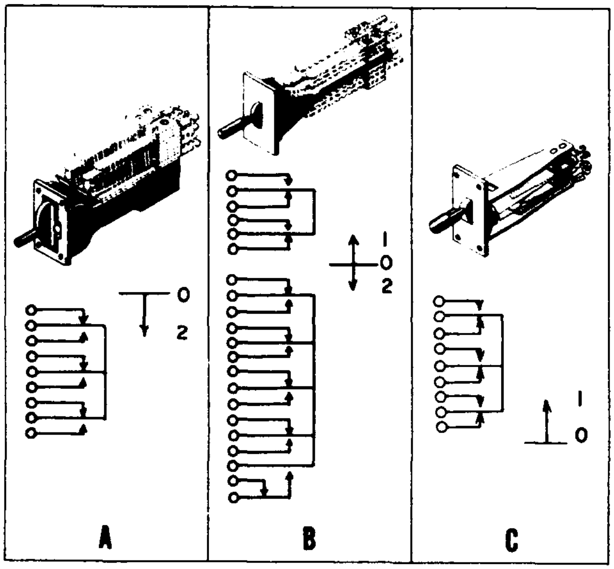

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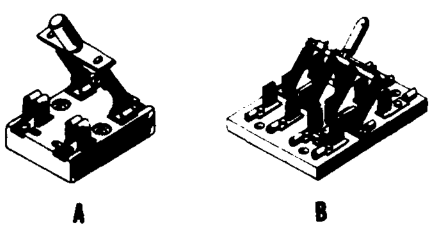
Figure 8-4.—Lever pileup switches.



1.102
Figure 8-5.—Knife switches.

load when a certain temperature is exceeded. Although not shown in the figure, various refinements such as adjustments and snap action may be incorporated in the switch.

In mercury thermostatic switches the mercury itself completes the circuit as it expands upward between two metallic contacts. The basic operating principle is illustrated in figure 8-6,B. When the temperature decreases, the mercury contracts and opens the circuit.

The principle of operation of gas thermostatic switches is illustrated in figure 8-6,C. When the gas is heated, it expands the bellows and closes the switch; when it is cooled, it contracts the bellows and opens the switch.

In each of the illustrations, only the basic principle of operation is shown. Certain refinements are generally added.

Figure 8-6,D, shows the thermostatic switch used in the crystal oven of one type of radio transmitter. The contact arrangement is for a single-pole, single-throw operation, and the switch is rated at 115 v and 0.75 ampere. The operating temperature is 170.6° F to 179.6° F, the temperature differential being 9°.

ROTARY PILEUP SWITCHES

Rotary pileup switches are so constructed that they open and/or close one or more electrical circuits; the contacts are arranged in a leaf, or pileup, fashion and they are actuated by a rotary motion.

One type of rotary pileup switch is illustrated in figure 8-7. As may be seen in the figure, there are six terminals. When the armature is moved upward by the rotary motion of the switch knob, two circuits are opened and two other circuits are closed.

This type of switch has numerous applications in low-voltage signal circuits.

ROTARY SELECTOR SWITCHES

Rotary selector switches, or nonpileup rotary switches, have many applications in electronic equipments. They may be made up of any number of sections, decks, or wafers depending upon the switching functions required. There are hundreds of possible contact arrangements. In many applications the switches are mechanically ganged to operate simultaneously from a single control (fig 8-8).

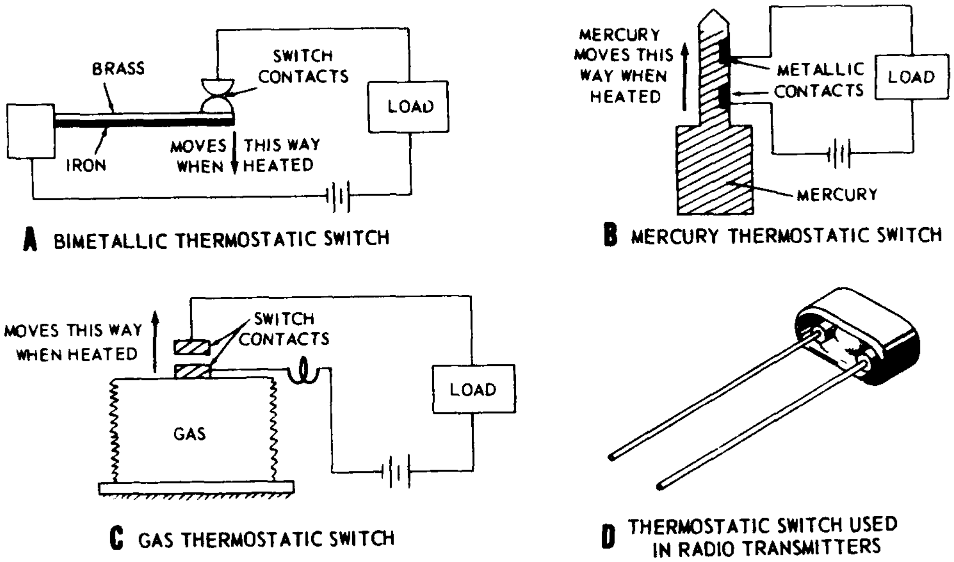


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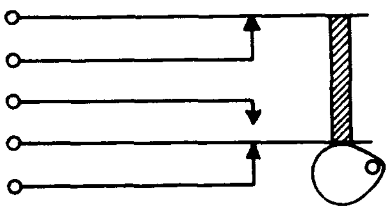
Figure 8-6.—Thermostatic switches.



1.104

Figure 8-7.—Rotary pileup switches.

One deck of a rotary selector switch is shown in figure 8-9. The code letters are also included at the leads extending from the various terminals. Short clips are indicated by the letter, X. Dummy lugs are indicated by the letter, D. Nonshorting rotary teeth (or blades) are indicated by crossed lines. The word, nonshorting, means that the width of the rotor tooth is less than the distance between adjacent contact clips. This means that as the rotor is turned, one circuit will be opened before the next one is closed. The shorting type is shown without the crossed lines. In this case the rotary tooth is wider than the distance between adjacent clips, and therefore as the rotor is turned, one circuit is closed before the preceding one is opened. Clips that are insulated from their associated lugs are indicated by the letter, S; long clips thus insulated are indicated by the letters, YS. When a clip is thus insulated, the lug may be connected to a clip on the reverse side. A through electrical connection is indicated when the rotor (or a portion of it) is shown in black. This means that the section of the rotor so marked in the figure is connected through to a bottom rotor, not shown.

TELEPHONE TYPE JACKS

The contact assemblies on telephone type jacks are divided into two categories: (1) the plug contact assembly and (2) the pileup contact assembly. The plug contact assembly includes the contact springs (and all others making electrical connection with them) that make direct contact with the plug when it is inserted. Both categories are illustrated in figure 8-10A.

Figure 8-10C, illustrates the common varieties of plug contact assemblies used on jacks and indicates the code designation for each.

The proper contact arrangement for jacks is determined with the aid of figure 8-10B. The plug contact assembly (J7) is distinguished from the pileup contact assembly (B), and the code designation for the plug contact assembly is determined from figure 8-10C. The type and

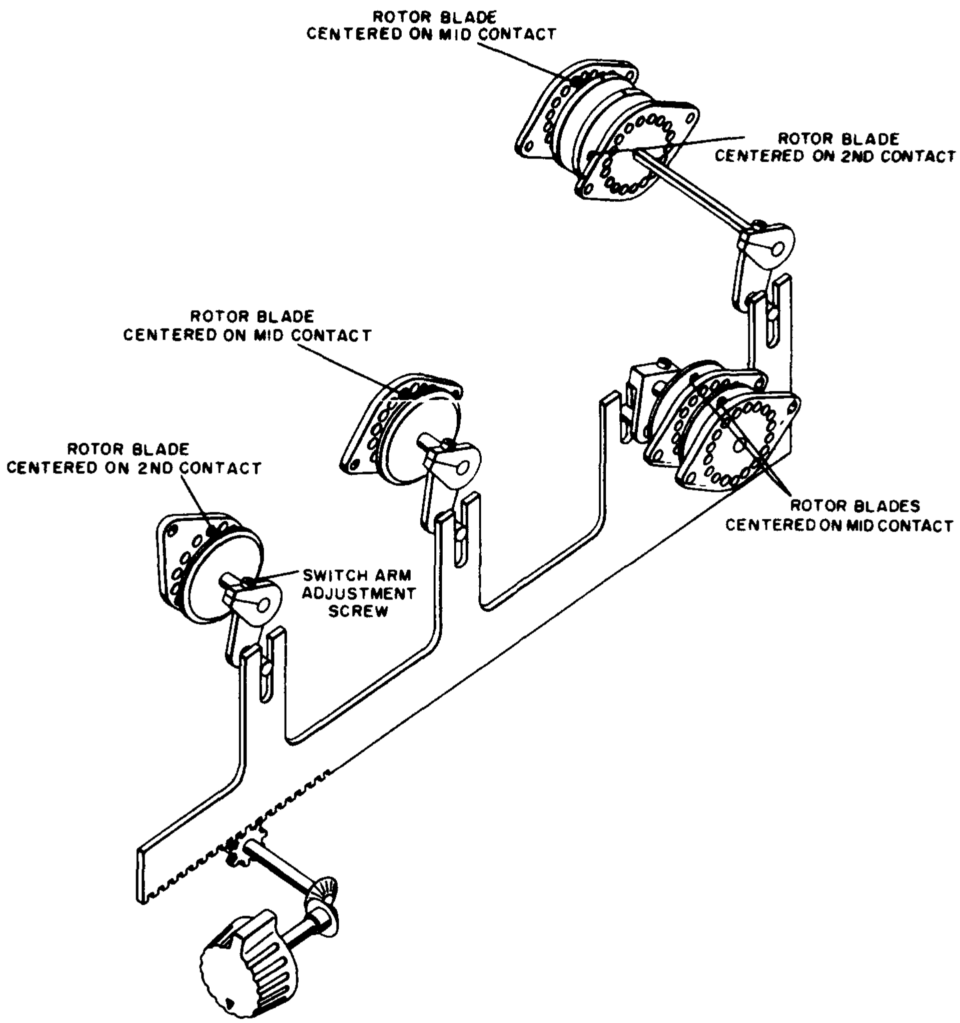


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Figure 8-8.—Rotary selector switches operated by gear and sliding bar.

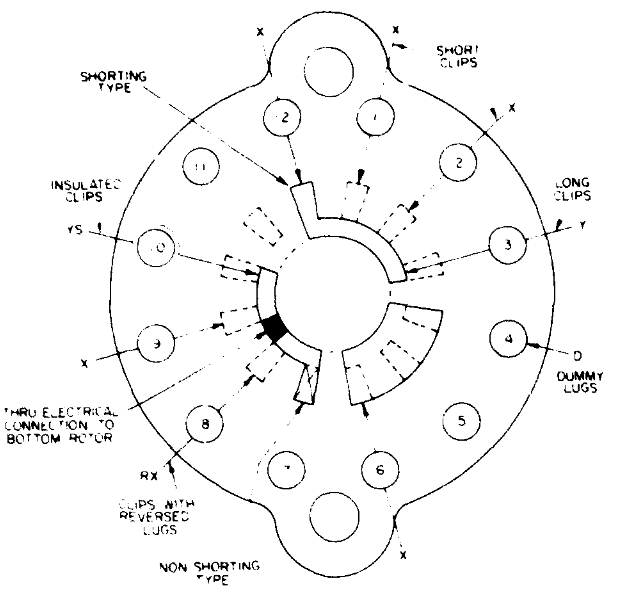
quantity of each basic form used to make up the pileup contact assembly are determined. In the case of part B of the figure the proper contact arrangement designation for the jack is "J7-1B."

Jacks are used in plug panels, teletype panels, phone units, and in many other applications.

RADIO RECEIVER BAND-SWITCHING CIRCUITS

Band-switching circuits in radio receivers commonly employ rotary selector switches. In order to trace the various circuits through these switches, it is necessary to pay careful attention to the schematic diagrams. The band-switching circuit of a receiver that is relatively easy to follow is included in figure 8-11.

The 4-position switch, S101B, in the input grid circuit of the oscillator tube, V105, selects 1 of 4 crystals. An additional set of contacts on S101B provides for grounding the three crystals that are not in use at any given time. The operating crystal is connected directly to the grid of V105. In the switch position, 1, shown in the figure, crystal X106 is connected



1.105

Figure 8-9.—Deck of rotary selector switch, showing contact arrangement and code letters.

between the grid of V105 and ground; the other three crystals are shorted to ground. In position 2, X107 is connected to the grid, and crystals X106, X108, and X109 are grounded.

The 4-position switch, S101A, mounted on the same shaft as crystal-selector switch S101B, connects filament potential to the proper channel-indicating lamp through S102. In the position shown in the figure, S101A provides circuit continuity for lamp (1); the other three lamps are open at the switch contacts.

Rheostat R117 enables the operator to control the brilliancy of the channel-indicator lamp and the dial lamps E109, E110, and E111.

The band-switching circuits of the AN/SRR-11 (fig. 8-12) are somewhat more involved, however, careful circuit tracing will enable one to follow the signal path.

Band switching for radio receiving set AN/SRR-11 is accomplished through the use of four 2-section, and two single-section rotary selector switches. The 5-position band selector on the front panel of the receiver is geared to a sliding bar similar to figure 8-8, and operates the selector switches to connect the appropriate components for the frequency band selected.

These selector switches connect the appropriate input and output transformers for the selected band, and connect the ganged sections of tuning capacitor C251 across the selected transformers to maintain tuning within the band. They also serve to short out transformers used for bands lower than the selected band, thereby preventing any absorption of the signal on the band in use.

Antenna matching links 0101 and 0102 (fig. 8-12) are provided to match antenna transformers T101 through T105 to either a high or low impedance input. With the links in the low impedance position the antenna is connected across the primary of the selected transformer with capacitor C106 connected between the center tap and the low side of the secondary. With the links in the high impedance position (as shown in fig. 8-12), the antenna is connected between the tap and the low side of the selected transformer secondary.

Antenna compensation switch S102 and capacitor C103, operated by the antenna compensation control on the front panel of the receiver, compensate for variations in antenna capacitance.

The wafers of all selector switches (fig. 8-12) are shown in band 1 position. The signal from the antenna is through C102, matching link 0101, C107 to S101A, and out of S101A via contact 3, through R101 to pin D of T101 in the first r-f amplifier section. The output signal voltage developed by the autotransformer action of T101 is fed back into S101A through contact 15 and out to the grid of the first r-f amplifier V101. S101A also connects the antenna section of tuning capacitor C251D across the secondary of T101. S101B is used to short out transformers associated with lower frequency bands than the selected band, and therefore is not used in band position 1.

The output of V101 (terminal H on J103) is fed to S126A in the second r-f amplifier section, out of S126A via contact 9 to pin B on the primary of r-f coupling transformer T126. The output from pin D on T126 is fed into S126A via contact 3, and out to the grid of the second r-f amplifier V126. C251C is connected across the secondary of T126 by contact 15 of S126A. S126B serves to short out transformers associated with bands below the selected band, and to connect capacitor C139 across the primary of T127, T128, or T129 when operating on bands 2, 3, or 4. S126B, therefore, is not used in band position 1.

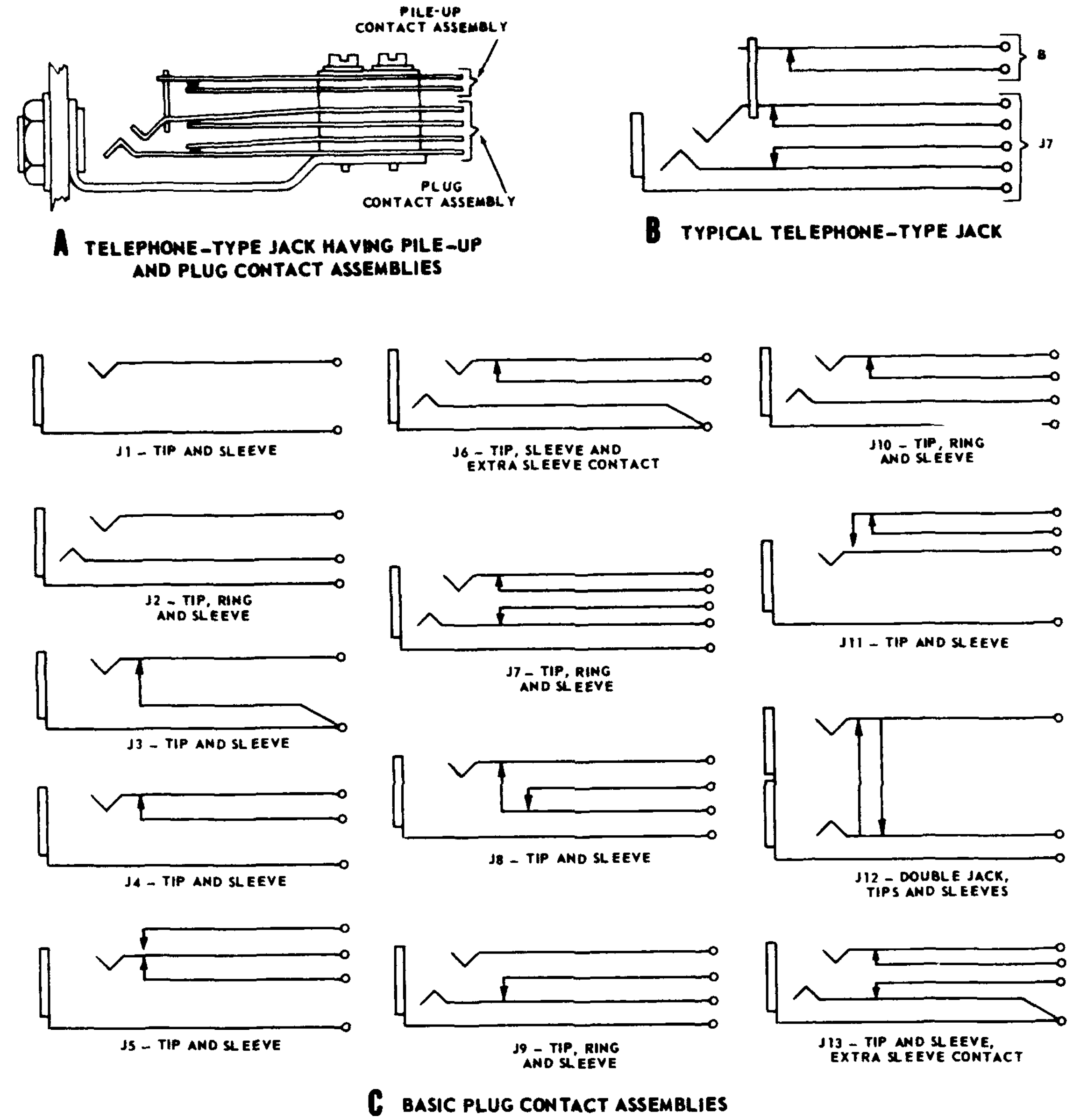


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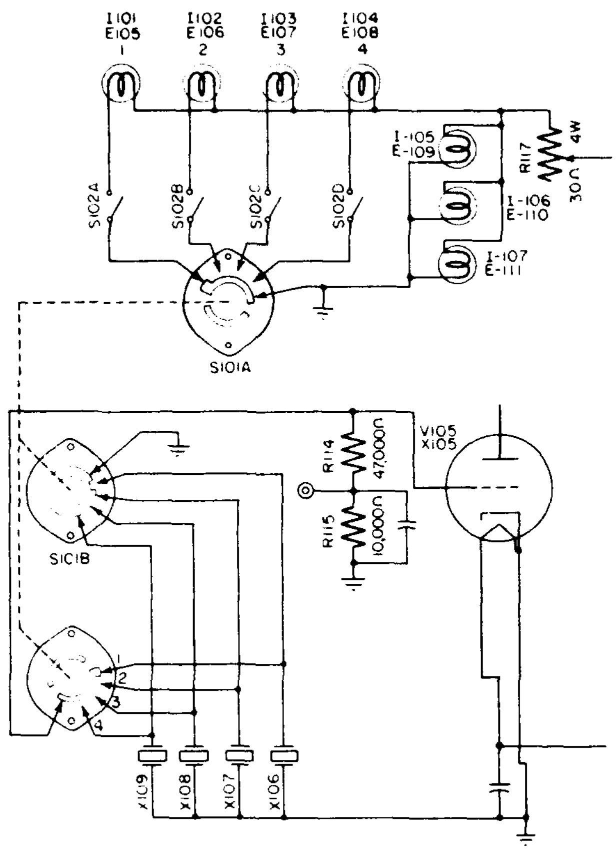
Figure 8-10.—Telephone-type jacks.

The output of the second r-f amplifier V126 at terminal H on J128 is coupled to the grid of mixer V151 through transformer T151. Transformer T151 is connected in the circuit by S151A in the same manner as described for T126 and S126A. S151B also is not used for band position 1.

Oscillator assembly Z201 in the oscillator section generates 60 kc above the signal frequency on frequency bands 1 and 4, and 200 kc above the signal frequency on the remaining bands. Oscillator signals for band 1 operation are from pin D on L201, into S201A via contact 9, out of S201A through R201, to the grid of V201. Oscillator feedback is from pin E on L201 into S201A via contact 3, and out of S201A through R202 to the cathode of V201. S201A also connects tuning gang capacitor



1.107
Figure 8-11.—Band-switching circuit of a receiver.

C251A in the oscillator tuned circuit. Contact 9 on S201B grounds pin D of coil L202 to prevent absorption of band 1 signals. The oscillator output is through C226, terminal E on J203, terminal B on J153, to the suppressor grid of mixer V151.

The output of mixer V151 during bands 1 and 4 operation is applied to the first i-f amplifier. The first i-f amplifier is bypassed on bands 2, 3, and 5.

Switches S701 and S702 in the first i-f section are two-pole, six-position, single-section, rotary selector switches. They serve to bypass the first i-f assembly in bands 2, 3, and 5. They also connect bandpass filter Z702 in the input circuit, and the B+ supply for operation of the first i-f assembly in bands 1 and 4.

In band position 1, the 60-kc output of mixer V151 at terminal H on J153 is fed to S701 and out on contact 16 to bandpass filter Z702. The output of Z702 is fed to the suppressor grid of V701. The 200-kc output of V701 is fed into S702 via contact 16 and out to the primary of T703. The secondary of T703 is the output to the second i-f assembly.

The circuits for band position 2 may be traced by rotating the arrows in all wafer switches one position in the direction shown. To trace the circuits for the remaining bands, rotate the switches the number of positions corresponding to the band to be traced.

RADIO RECEIVER AND TRANSMITTER REMOTE-CONTROL TRANSFER SWITCHBOARDS

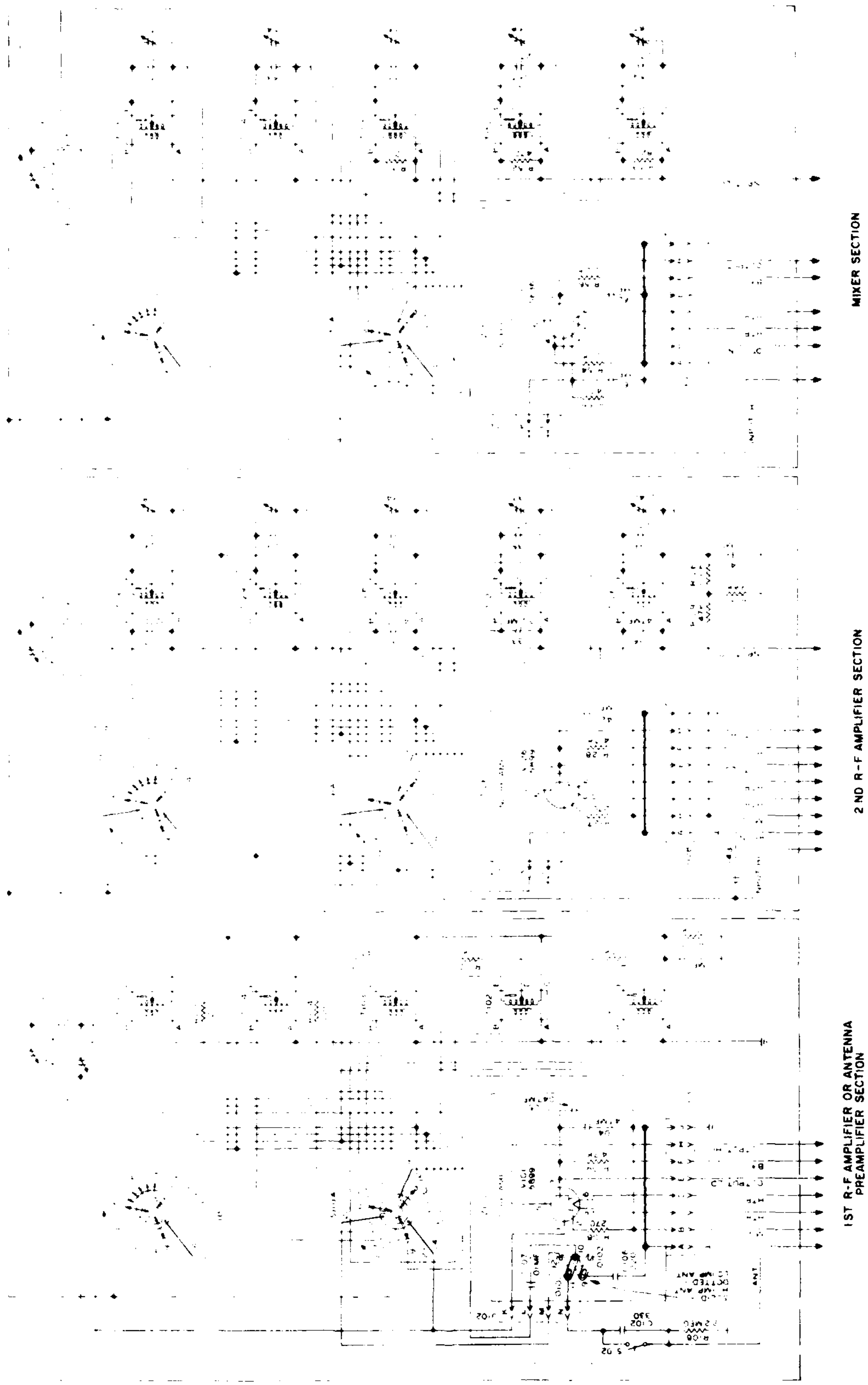
Radio remote-control transfer plug panels have become too cumbersome to be used in shipboard radio installations on modern Navy ships. Therefore, control panels utilizing switches instead of plugs and patchboards are being installed in new construction and in conversion jobs. Two unit-constructed panels (one for receivers and one for transmitters) now provide all of the facilities that were available in three types of plug panels (the receiver transfer panel, the transmitter transfer panel, and the radiophone transfer panel), and in addition afford greater flexibility in the remote-control system. These units are Receiver Transfer Switchboard, Type SB-82/SRR, and Transmitter Transfer Switchboard, Type SB-863/SRT.

RECEIVER TRANSFER SWITCHBOARD

An external view of the Receiver Transfer Switchboard, Type SB-82/SRR, is shown in figure 8-13. A simplified schematic diagram of a portion of the internal switching arrangement is shown in figure 8-14.

The receiver switchboard has 5 vertical rows of 10 double-pole, single-throw (ON-OFF) switches that are continuously rotatable in either direction.

One side of each switch within a vertical row is wired in parallel with the same sides of the other nine switches within that row. Similarly, the other side of each switch is wired in parallel horizontally with the corresponding sides of each of the other four switches in a horizontal row. This method of connecting the switches gives rise to the term CROSS-MAT


MIXER SECTION
2ND R-F AMPLIFIER SECTION
1ST R-F AMPLIFIER OR ANTENNA PREAMPLIFIER SECTION

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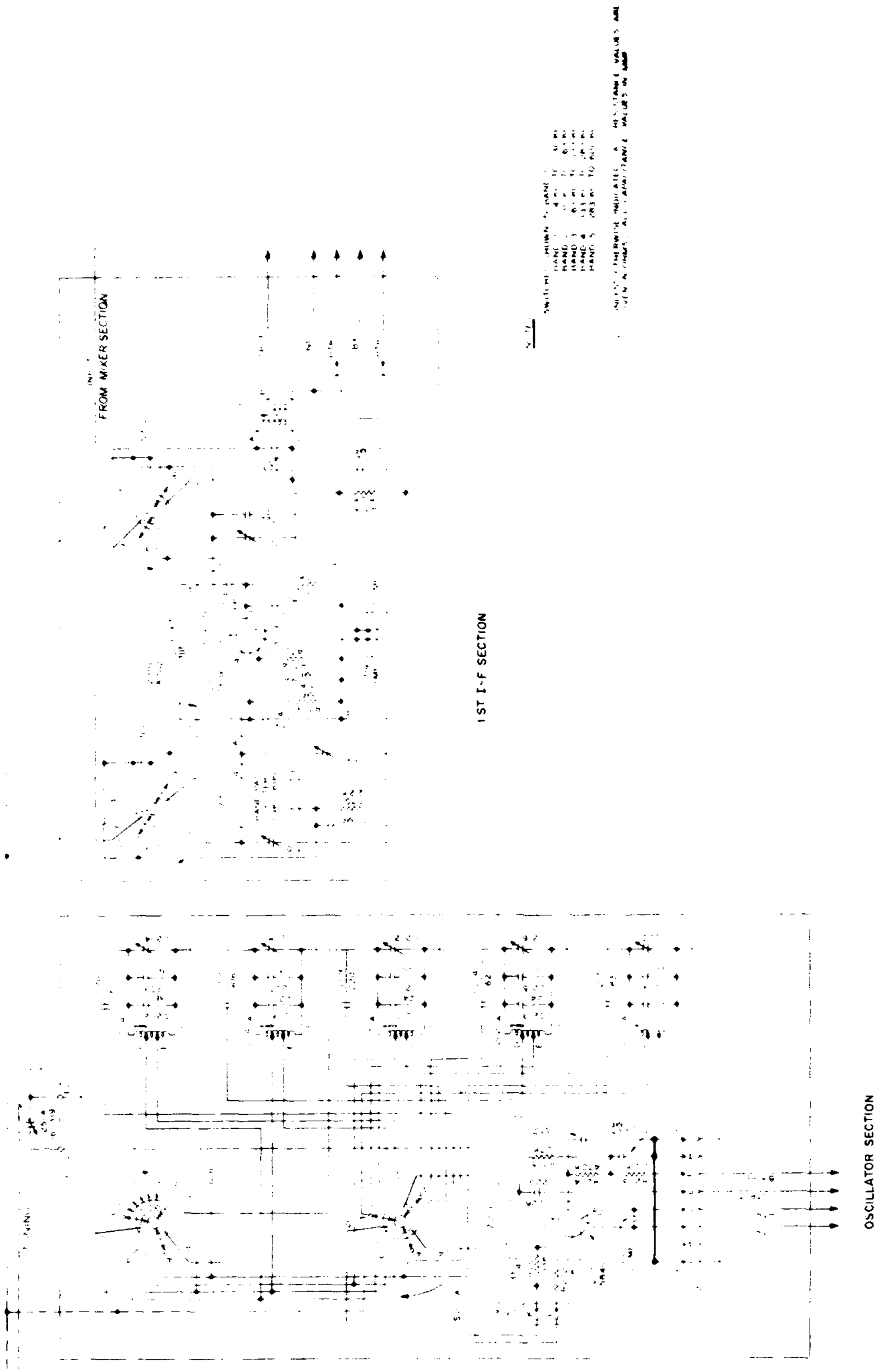

Figure 8-12.—Band-switching circuits—Radio Receiving Set AN/SRR-11—Continued.

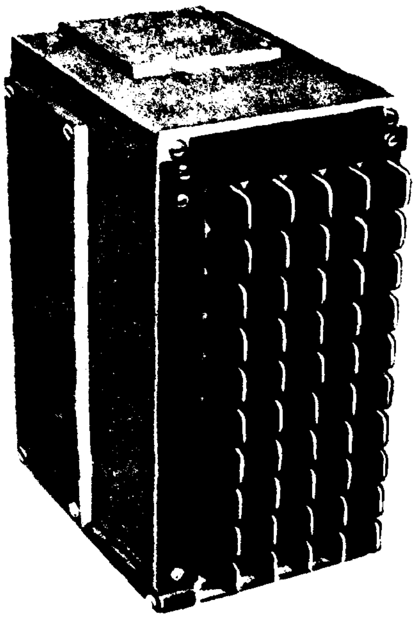

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Figure 8-13.—External view of the Receiver Transfer Switchboard type SB-82/SRR.

PARALLELING, and permits a high degree of flexibility.

The audio output from the receiving equipments, connected to the five vertical rows of switches, may be fed to any or all of the remote stations by closing the proper switch or switches. For example, the audio output from the L-F receiver may be fed to remote radiophone station No. 1 by closing switch 16; it may be fed to all of the remote stations by closing all of the switches in the left-hand vertical column.

Shielded leads are used for the audio circuits.

The knob of each switch is marked with a heavy white line to provide visual indication of the communication setup. In general, there are more remote stations than there are receivers, and therefore the switchboards are normally mounted in a vertical position (as in fig. 8-13). This arrangement permits the outputs from 5 receivers to be fed to the 5 vertical rows and up to 10 remote stations to be fed from the 10 horizontal rows of switches. Switchboards are furnished with the knobs in the OFF position when the white line is vertical.

If it becomes necessary to employ a system where there are 10 receivers and 5 remote stations, the switchboard may be mounted in a horizontal position and each switch knob rotated 90° with respect to the shaft. All shafts have two flat sides for setscrews so that this change can be made if desired. The purpose of rotating the switch knobs with respect to the shaft is to standardize the setup so that the switches will be in the OFF position when the white line is vertical. To further standardize all installations, receivers are always connected to the vertical rows of switches, and remote stations are always connected to the horizontal rows of switches after the orientation (vertical or horizontal) of the switchboard has been determined.

It should be noted that only the receiver audio output circuit is connected to the switchboard. This is true also of the receiver transfer plug panel used in earlier installations. Transmitter transfer switchboards, however, handle several other types of circuits in addition to audio circuits.

TRANSMITTER TRANSFER SWITCHBOARD

Transmitter Transfer Switchboard type SB-863/SRT has replaced type SB-83/SRT. The SB-863/SRT (fig. 8-15) has ten 20-position rotary selector switches, in two vertical columns. Each rotary switch corresponds to a remote control station, and each switch position (1 through 19) corresponds to a controlled transmitter. Thus switching control is provided for up to 10 remote control stations, and 19 transmitters. When more than 10 remote stations, or 19 transmitters, are to be connected, additional transfer switchboards may be installed. Position 20 of each rotary switch is provided for connections to an additional transfer switchboard to control extra transmiters. The switches consist of 12 wafers which serve to connect the start-stop indicator, keying, 12-v d-c microphone, carrier control, and carrier indicator circuits for the various transmitters.

Any of the remote stations may be connected to control any of the transmitters in the system. For example, to connect remote station No. 1 (fig. 8-16) to control the TED transmitter,

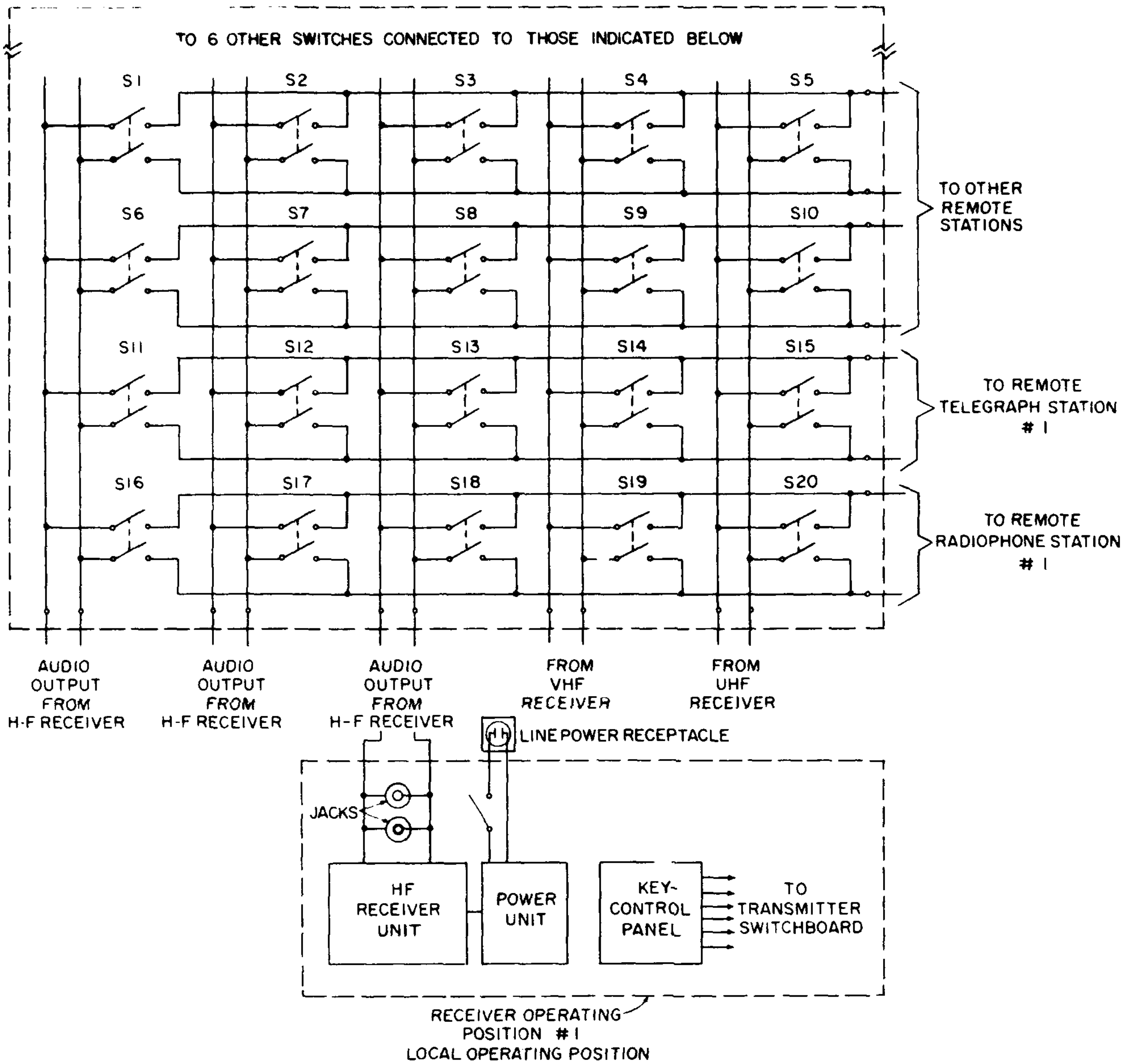

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Figure 8-14.—Simplified schematic diagram of the receiver transfer switchboard type SB-82/SRR.

rotary switch No. 1 (S1) is placed in position 1. To control the AN/GRC-27 from remote station No. 1, switch S1 is placed in position 2. Switch 2(S2) is used for remote station No. 2 in the same manner.

The remote stations assigned to each rotary switch, and the transmitters assigned to positions 1 through 19, are engraved on the engraving plates when the switchboard is installed (fig. 8-15). If an extra switchboard is installed, switch position No. 1 on the second switchboard is assigned to transmitter No. 20, position No. 2 to transmitter No. 21, etc. Thus, if remote station No. 2 is to have control of transmitter No. 22, switch No. 2 on the first switchboard is placed in position 20, and switch No. 2 on the additional switchboard is placed in position 3.

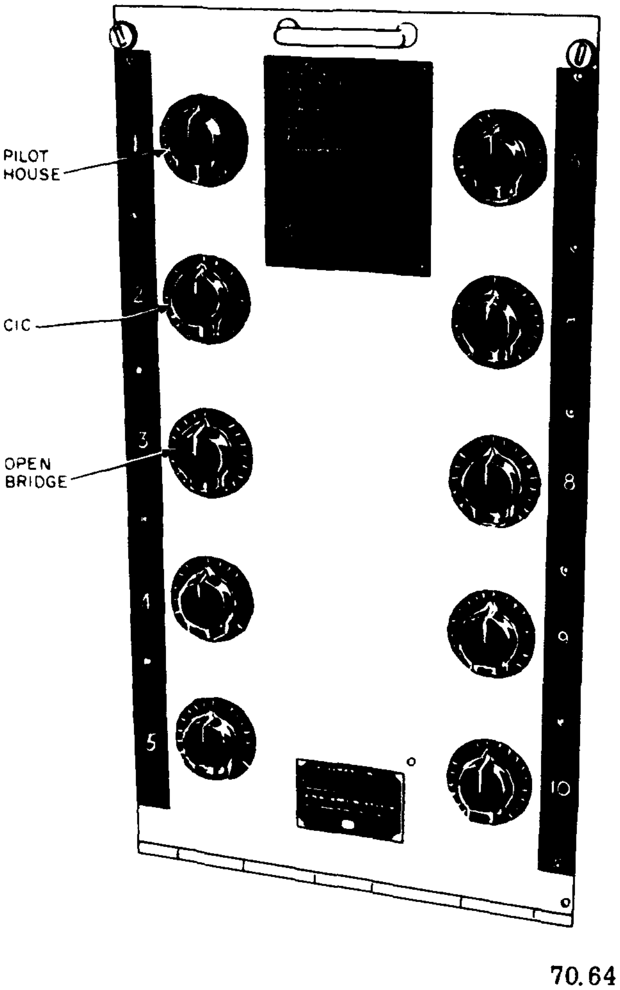

Figure 8-15.—Transmitter transfer switchboard—SB-863/SRT.

INTERCONNECTIONS BETWEEN TRANSFER SWITCHBOARDS

Figure 8-17 illustrates possible interconnections between the various switchboards located in Radio Central, Radio II, and Radio III.

Increased flexibility may be obtained by the use of a large number of switchboards in Radio Central and a smaller number of switchboards in Radio II and Radio III. Most of the space on two bulkheads may be taken up by the switchboards in Radio Central.

SWITCH CONNECTIONS BETWEEN RADIOPHONE UNIT AND TRANSMITTER

Generally, a radio transmitter connects through the transmitter transfer switchboard to a radiophone unit. However, in figure 8-18 the transmitter transfer switchboard has been omitted; and only a simplified diagram of the transmitter (Navy Model TED-8), showing the control circuits, is included.

The line power switch, S1, is a 2-pole, single-throw switch in the 60-cycle, single-phase, power-line circuit and must be closed before the equipment can be started with the start-stop switch at the transmitter or RPU. In an emergency, power can be quickly removed from the entire equipment by throwing the line power switch to the EMERGENCY OFF position.

The local start-stop switch, S2, in the transmitter is a momentary contact (nonlocking) switch used to start or stop the equipment after S1 has been closed. Momentary closure of S2 on the START side energizes the equipment start-stop relay, K1, which locks itself in the closed position through contacts K1A, the thermal cutout relay contacts, and resistor R. Relay K1 remains energized until its coil is shorted when S2 is moved to the STOP position.

The local remote switch, S3, affords local or remote control of the operation of the transmitter. When S3 is set to LOCAL, S3(a) connects the parallel combination of the local handset, the microphone jack, and the local carrier-control switch in series with the input windings of the input transformer, T1 (winding 1-2 in series with winding 3-4), thus providing local control of the carrier. Indicating and control functions are disconnected from all remote units by operation of S3(a), S3(b), S3(c), and S3(d).

When S3 is turned to the REMOTE position, the following sequence of events takes place:

1. Switch S3(a) connects the T2 secondary and the microphone or key jack in the RPU as a parallel combination across the transmitter T1 primary (1-2 winding in series with the 3-4 winding) and disables the local carrier-control circuits. The circuits through the handset microphone in the RPU are from the -12-v supply (terminal 7), the T2 primary, terminals C and D of the handset extension jacks by way of the push-to-talk switch (not shown in the RPU), and ground return at terminal 8. The circuits through the handset receiver in the RPU are

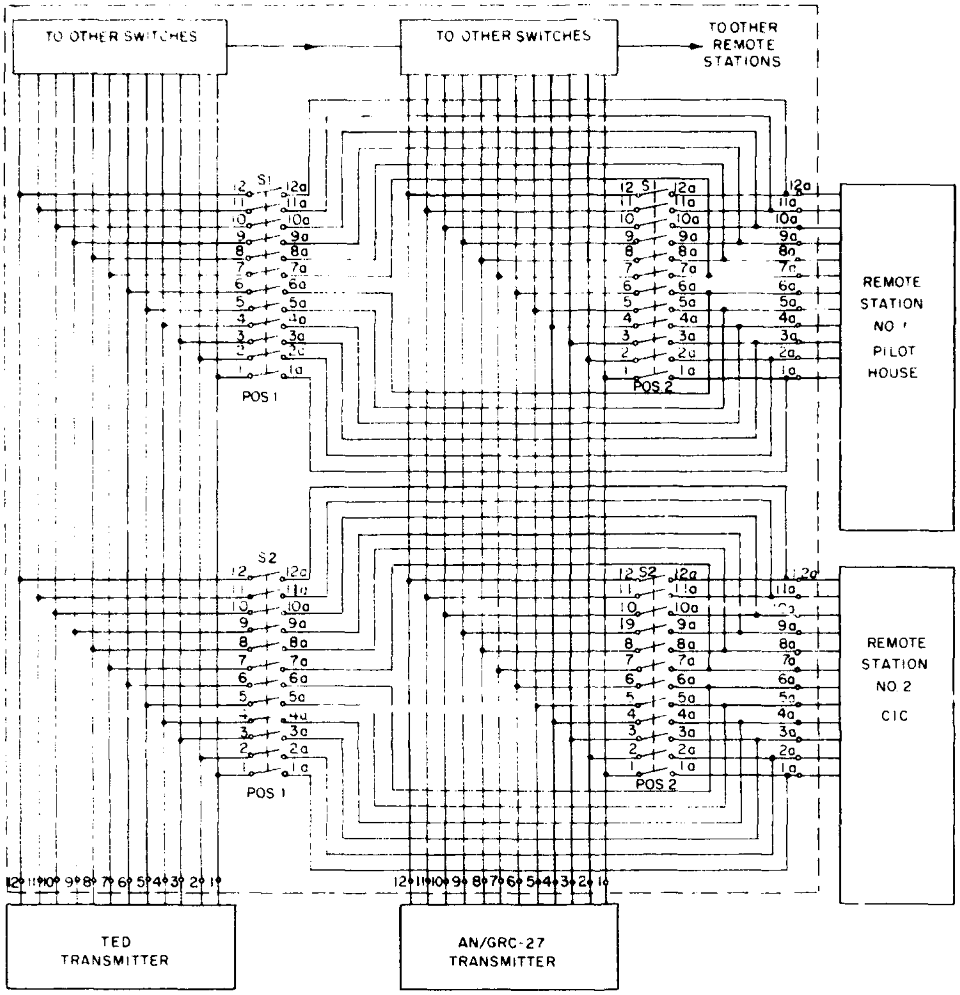

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Figure 8-16.—Simplified schematic diagram of transmitter transfer switchboard SB-863/SRT, showing first two positions of rotary switches 1 and 2.

from terminals A and B of the handset extension jacks, the earphone-level potentiometer, and terminals 13-14 to the associated receiver via the receiver transfer switchboard (not shown).

2. Switch S3(b) connects the common lead to the start-stop circuit to the stop switch in the RPU.

3. Switch S3(c) connects one side of the 115-v a-c line to the RPU power indicator by way of terminal 4. The other side of the 115-v line is always connected directly to the other side of the power indicator.

4. By means of S3(d), -12 v is applied to the RPU for microphone current.

The audio monitoring circuit involves the circuits connected to terminals 5, 6, 10, 13, and 14 on the terminal board. The audio monitoring circuit enables the operator to listen to the

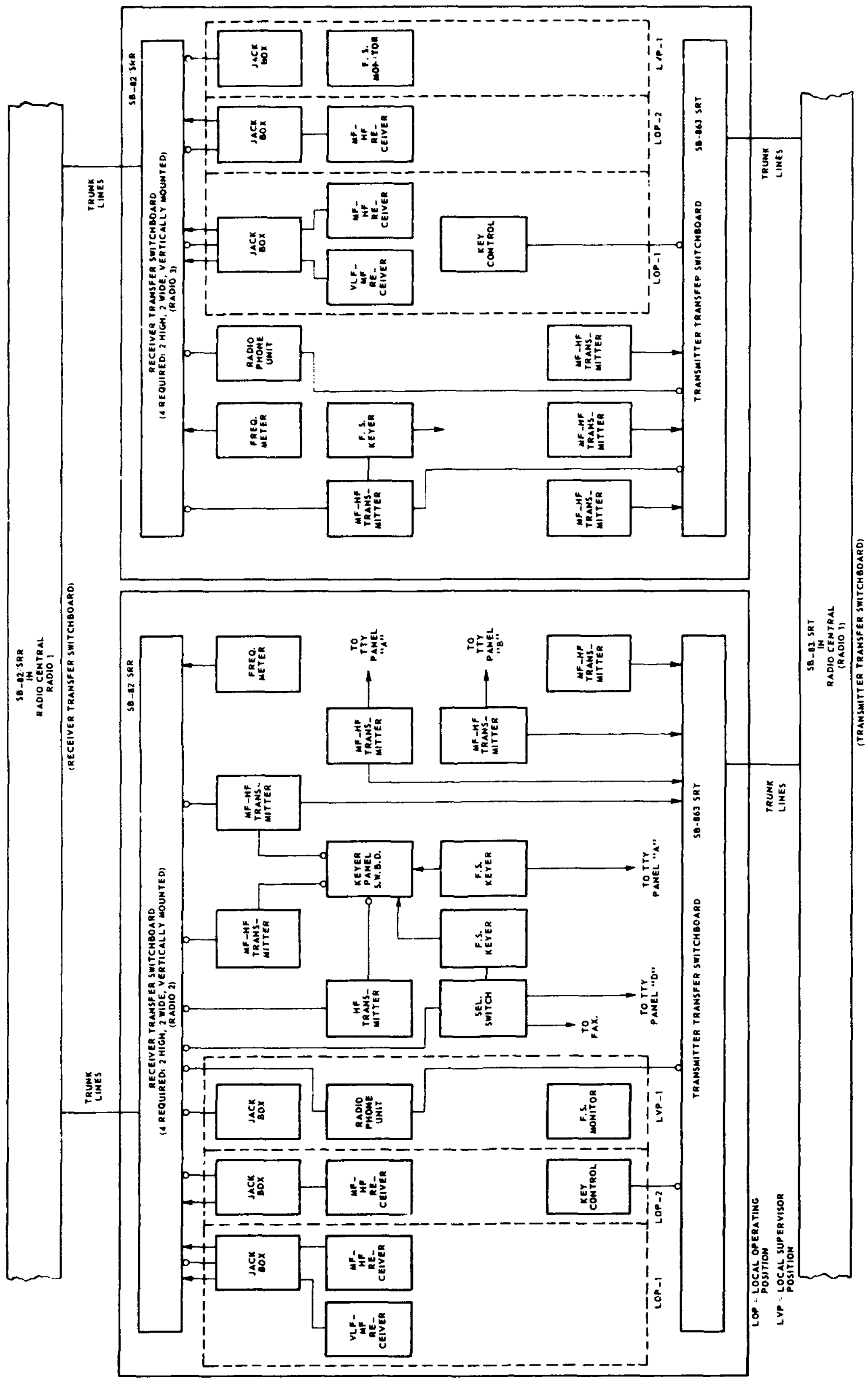

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Figure 8-17.—Interconnections between transfer switchboards.

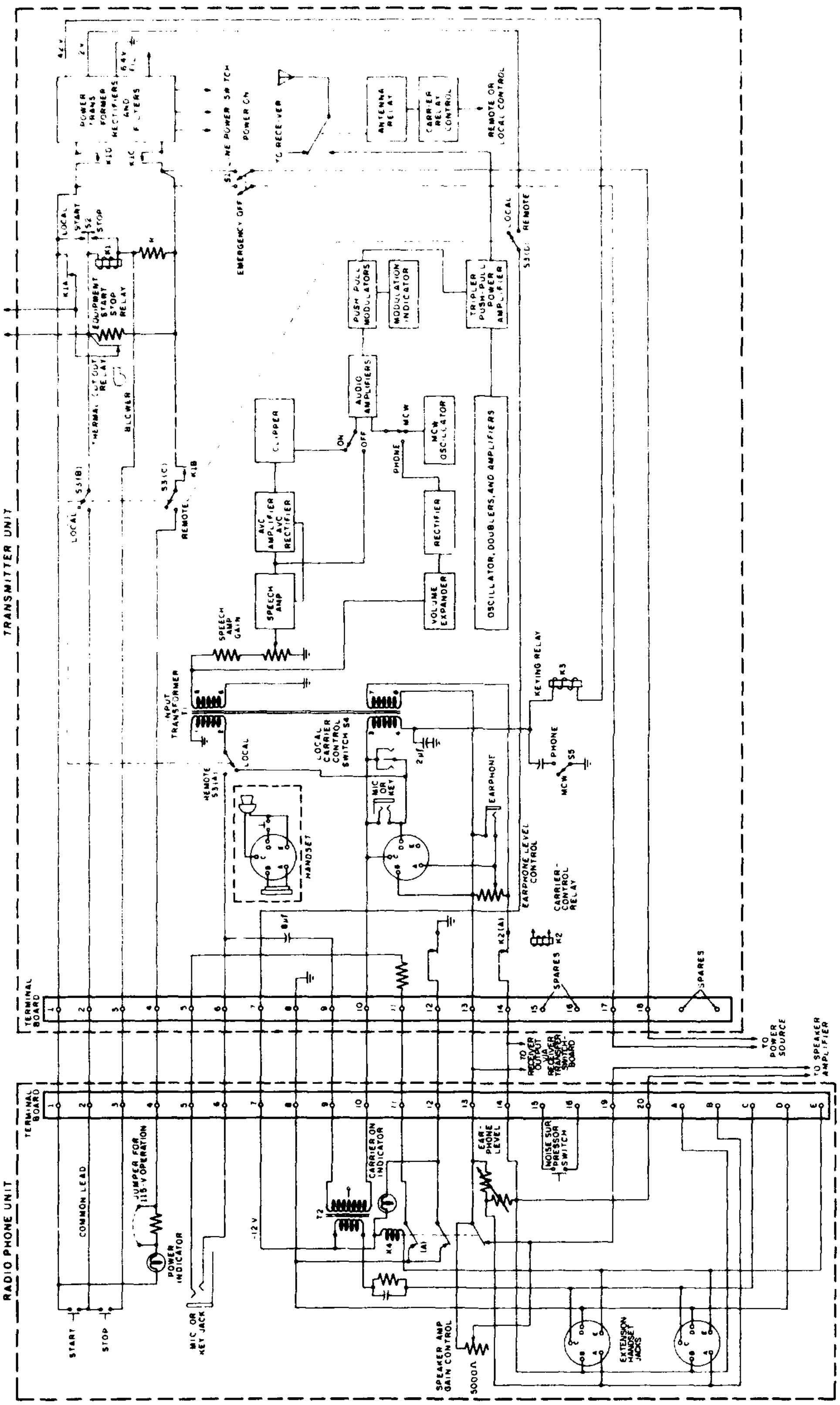

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Figure 8-18. —Switch connections between radiophone and transmitter.

output of the receiver when the transmitter is off and to listen to speech "sidetone" when the transmitter is being used. Circuits are provided so that this may be done either locally or at a remote location. The audio signal from the receiver is brought into terminals 13 and 14.

When the transmitter carrier is off, relay contacts K2(a) are closed (K2 is deenergized), and the audio signal from the receiver is fed via K2(a) to the earphone-level volume control at the transmitter and to the 7-8 winding of T1. The receiver may be monitored locally by plugging the earphones into the earphone jack at the transmitter, because this jack is connected across a part of the earphone-level volume control.

When the transmitter carrier is on, relay K2 is energized and contacts K2(a) are open. This condition disconnects the receiver audio signal circuit from the earphone-level control at the transmitter, the associated earphone jack, the receiver handset plug terminals A and B, and the 7-8 winding of T1. The transmitter sidetone signal is picked up by the secondary, 7-8, winding of T1 and impressed across the earphone-level control for local monitoring. The remote monitoring signal is picked up from the control lines on which the signal is normally present during voice operation.

When S5 is in the PHONE position and the local microphone handset press-to-talk switch is operated, keying relay K3 is energized. This action indirectly energizes carrier control relay K2, which disconnects the receiver from T1, as previously described. Thus, the receiver is disconnected when the transmitter carrier is on. The same action takes place in remote operation, except that relay K4 in the RPU energizes K3 by applying ground to terminal 3 of the 3-4 winding of T1 via terminals 8 and 11 and contacts K4(a).

RECEIVING-ANTENNA DISTRIBUTION SYSTEMS

Shipboard Antenna Details, NavShips 900121 (revised), contains information concerning antenna distribution systems. Antenna transfer panels and filter assemblies have replaced older systems on board ship. Filter type multicouplers were discussed in chapter 5 of this course.

SYSTEM EMPLOYING TRANSFER PANELS

A receiving-antenna distribution system, using antenna transfer panels, is shown in figure 8-19. The transfer panels are interconnected so that a receiver in any radio space may be connected to any receiving antenna, regardless of its topside location.

Two different views of the antenna transfer panel, type 23406, are shown in figure 8-20 (A and B) a simplified schematic diagram is shown in figure 8-20,C. These transfer panels provide the means by which as many as four radio receivers may be operated simultaneously from one antenna. At the transfer panel, each antenna is connected to a vertical row of four jacks. One jack is connected directly to the antenna; the other jacks are connected in parallel through 600-ohm decoupling resistors. The receivers connected to the three decoupled jacks operate at reduced efficiency.

There are nine interspace lines (one for each vertical row of four jacks) that connect to the various antennas (fig. 8-20,C). These lines connect to the vertical rows composed of four jacks (fig. 8-20,A). The escutcheon plate at the top of each line of four jacks is marked to indicate the remote termination of that line.

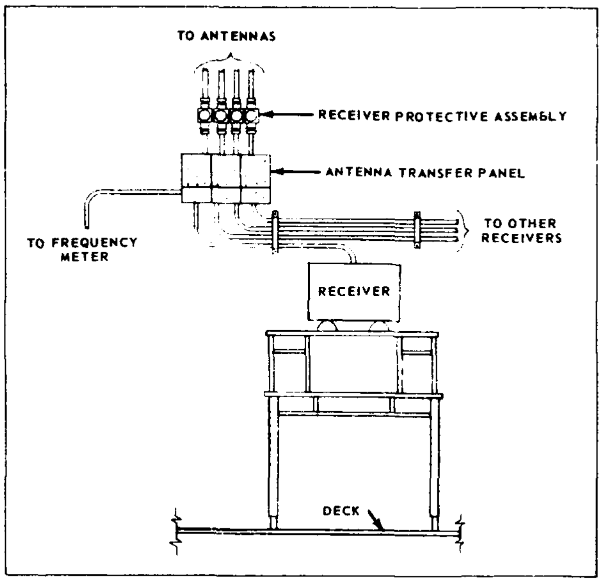

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Figure 8-19.—Receiving-antenna distribution system, using antenna transfer panels.

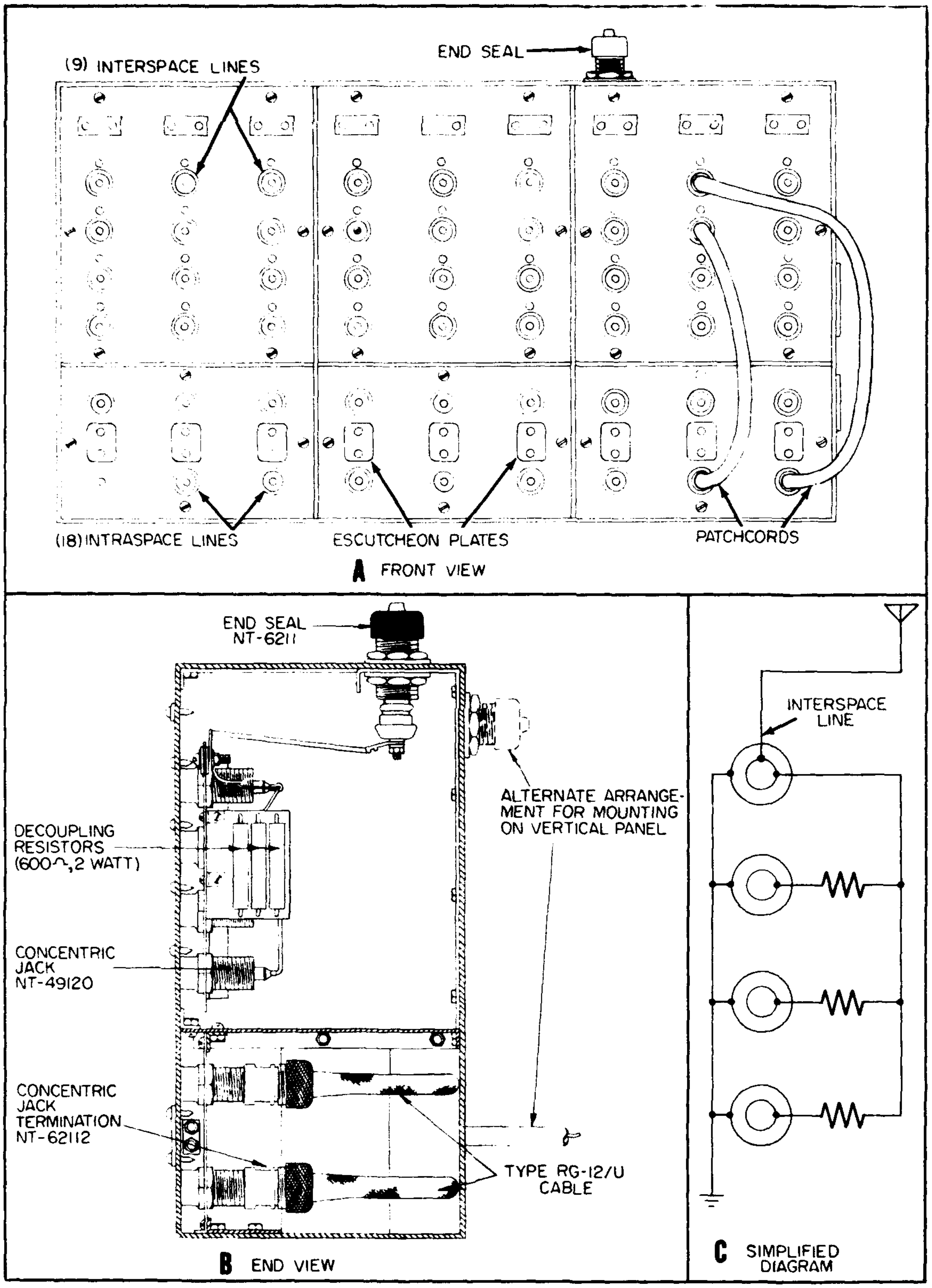

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Figure 8-20.—Antenna transfer panel, type 23406.

The 18 intraspace lines (lower 2 rows of jacks) connect to terminal boxes located at the various receiver, frequency meter, or other equipment positions. White escutcheon plates are mounted between each pair of jacks to enable the operator to mark the respective communications channel, frequencies, or schedules thereon. Patch cords are provided to complete the connections between the various jacks on the front of the panels.

SYSTEM EMPLOYING FILTER ASSEMBLY

A receiving-antenna distribution system, using a filter assembly, is shown in figure 8-21. This type of distribution system makes possible the multiple operation of a maximum of 28 radio receivers from a single antenna. It is generally preferable however, to limit the total number of receivers to 7.

This filter assembly or "multicoupler" provides 7 r-f channels in the frequency range from 14 kc to 32 mc. Any or all of these channels may be used independently of, or simultaneously with, any of the other channels. Connections to the receivers are made by means of coaxial patch cords and a patch panel.

An external view of the filter assembly is shown in figure 8-21,A. Separation of the frequency range into channels is accomplished by combinations of filter subassemblies, which plug into the main chassis. Each filter subassembly consists of complementary high-pass and low-pass filter sections, the common crossover frequency (F_c) of which marks the division between channels.

The filters not only guard against interference at frequencies falling outside the channel being used, but also prevent receivers connected to alternate rows of jacks from interacting with each other when their tuning and trimming adjustments are made.

A set of nine filter subassemblies is available, any six of which may be used at one time. The filter subassemblies are sealed units consisting of inductors and capacitors and are terminated in 4-terminal plugs, which are designed to engage octal receptacles on the main chassis. The subassemblies have numbers stamped on them that indicate their crossover frequencies. These numbers can be viewed through windows in the front panel. The six subassemblies that are used are assembled in the order of decreasing frequencies from left to right, as viewed from the front of the panel.

The filter panel (fig. 8-21,B) contains 1 antenna input jack, 28 output jacks, 21 decoupling resistors, and 6 octal sockets. The antenna input jack and the 28 output jacks are all Navy type-49120 r-f connectors. [In the AN/SRA-12 Receiving Filter Assembly, these connectors have been changed to receptacle connectors UG-1111/U (and plug connectors UG-968/U) which are improved quick-disconnect type r-f connectors.] The filter subassemblies plug into octal sockets in the rear of the main chassis (not shown).

To keep the losses to a minimum, the input and output of the filter assembly should be terminated in 180 ohms, however, only a slight reflection loss (of the order of 1.0 db) results when the input is terminated in 70 ohms.

Because Navy communications receivers generally operate throughout frequency bands that exceed the widths of the channels normally provided by the filter subassemblies, a given receiver must be connected to the particular row of output jacks that provides the signals of the desired frequency. For example, if a receiver is tuned from some frequency in the 7- to 14-mc band to some frequency in the 14- to 32-mc band, the patch cord would have to be moved from the output of the 14- to 7-mc subassembly unit to the output of the 32- to 14-mc subassembly unit.

When necessary, the bands of frequencies available in a given row of output jacks may be changed either by using different combinations of filter subassemblies or by removing various subassemblies and inserting "shorting plugs." provided with the equipment. These shorting plugs provide continuity between successive subassemblies, as required when testing or when a subassembly is removed for any reason, without the necessity for changing the position of the remaining subassemblies.

The red-painted jacks at the bottom of each row are directly connected to the subassemblies and should be used whenever maximum signal strength is desired. The other 3 jacks in each row are decoupled by 300-ohm resistors and are best suited for use with relatively strong signals (fig. 8-21C). In the ideal arrangement, only one receiver is connected to each vertical row of jacks, and that receiver is connected to the bottom jack in each row. This means that seven receivers are fed from each antenna. At frequencies somewhat removed from the crossover points, the performance of each of these seven receivers should be comparable with that

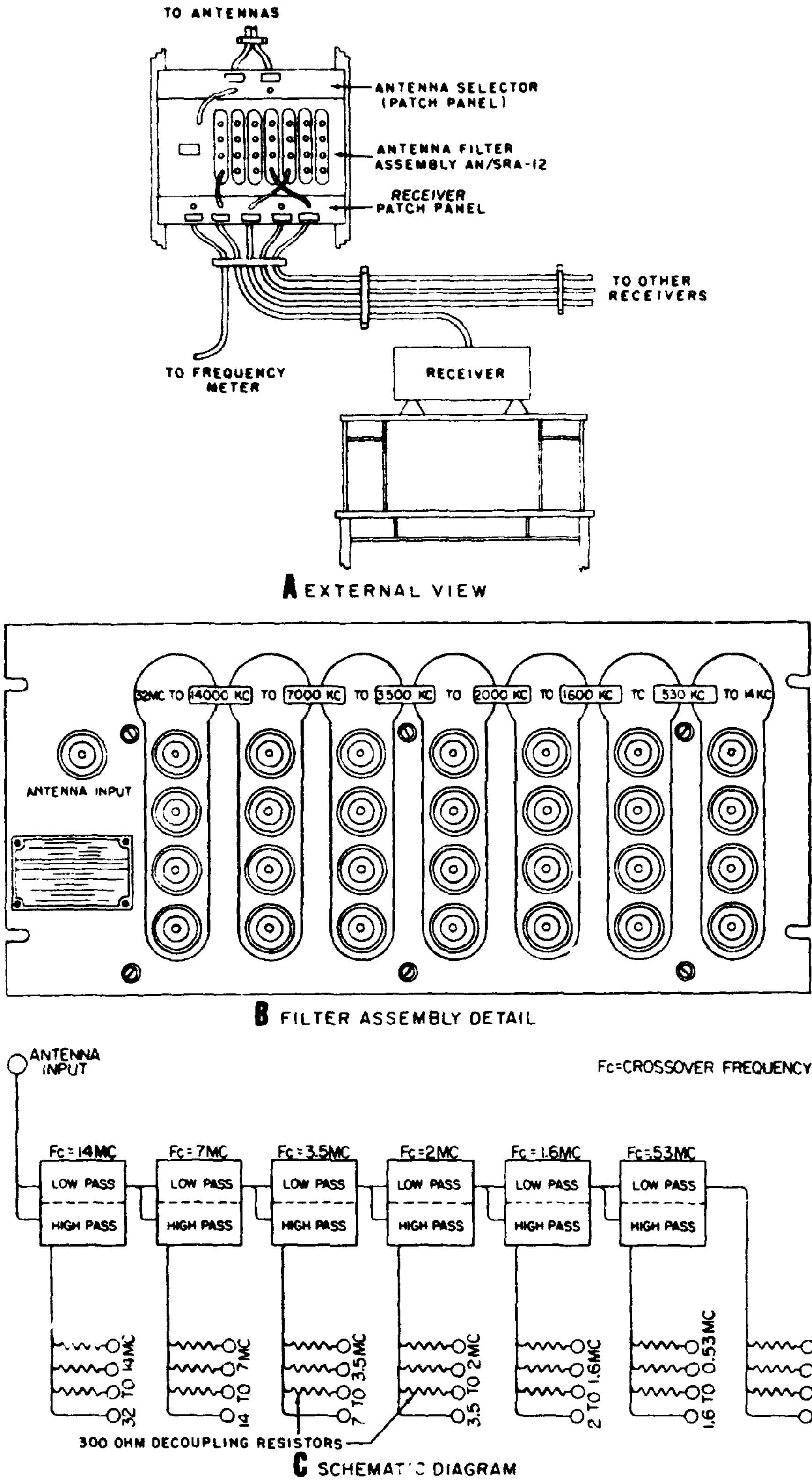

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Figure 8-21.—Receiving-antenna distribution system, using antenna filter assembly.

obtained if a given one of the receivers were connected directly to an antenna. Likewise, the performance of 21 receivers connected to the "decoupled jacks" should be comparable with the performance of 3 receivers decoupled in like manner, using conventional patch panels with a given antenna.

DISTRIBUTION OF RADAR INFORMATION

The distribution of radar information is somewhat involved, and complex switching equipment is needed. There are various types of switching gear and various combinations of radar equipments and radar repeaters.

For the purpose of this chapter, a brief discussion of Data Switching Group OA-496/SSA is included. Included with this switching group is Video Amplifier Assembly AM-518/SSA, Rotary Switch SA-243/SSA, and Rotary Switch SA-247/SSA (Fig. 8-22). For remote servo operation, Rotary Switch SA-243/U (not shown) is also needed at other repeaters.

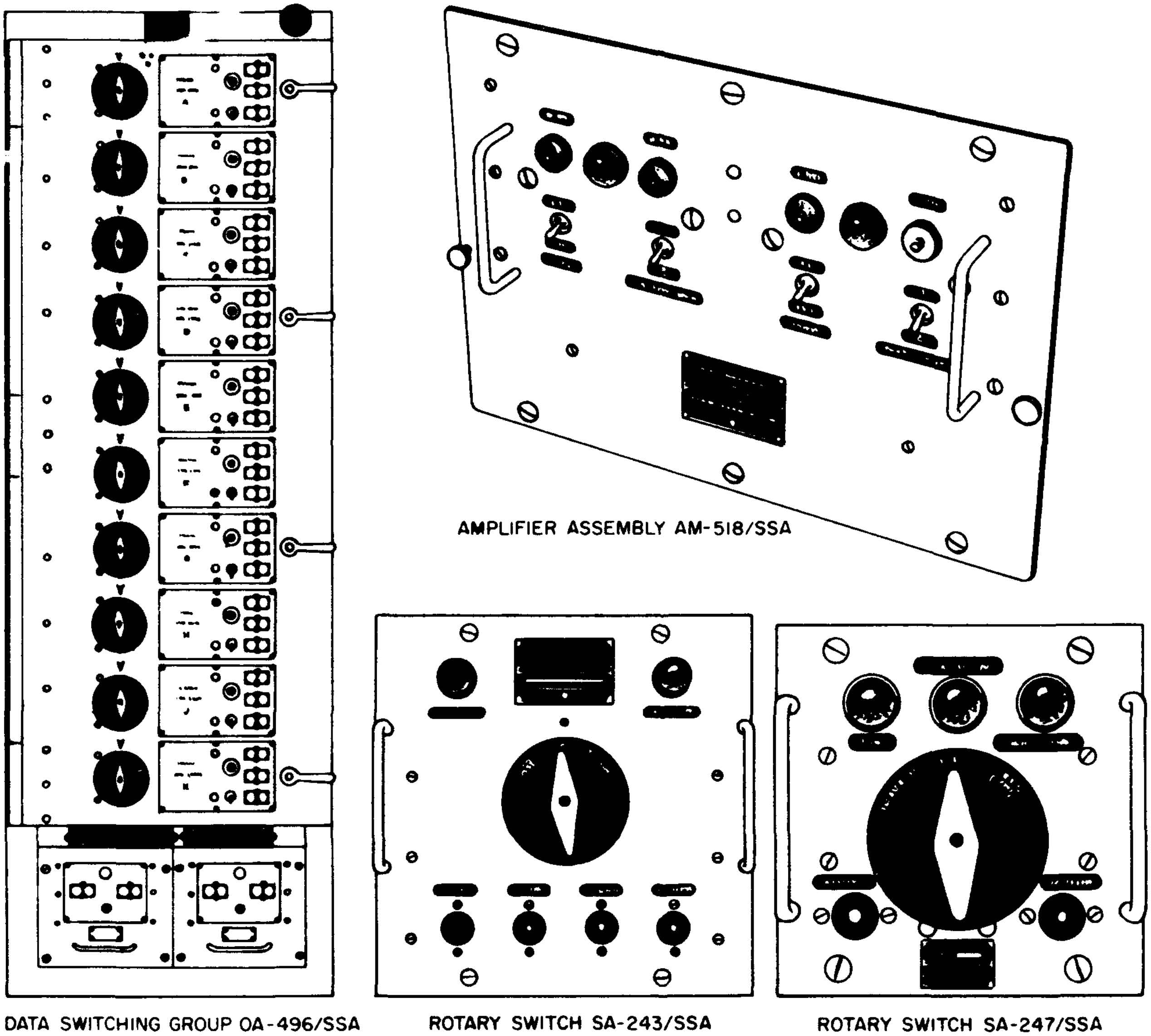

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Figure 8-22.—Data switching group OA-496/SSA, Amplifier Assembly AM-518/SSA, and Rotary switches SA-243/SSA and SA-247/SSA-front panels.

As indicated in the block diagram (fig. 23), the purpose of the equipment is to stribute radar information to remote incators throughout the ship. The number of data vitching groups actually required in any particar installation depends on the number of signal urces and the number of repeaters to be served. Only a relatively simple system is shown in this figure.

Each of the 10 radar selector switch units in the data switching group provides for the selection (remote or local) of any one of seven radar-data inputs (only 2 are shown in the figure), as selected by the operator at any

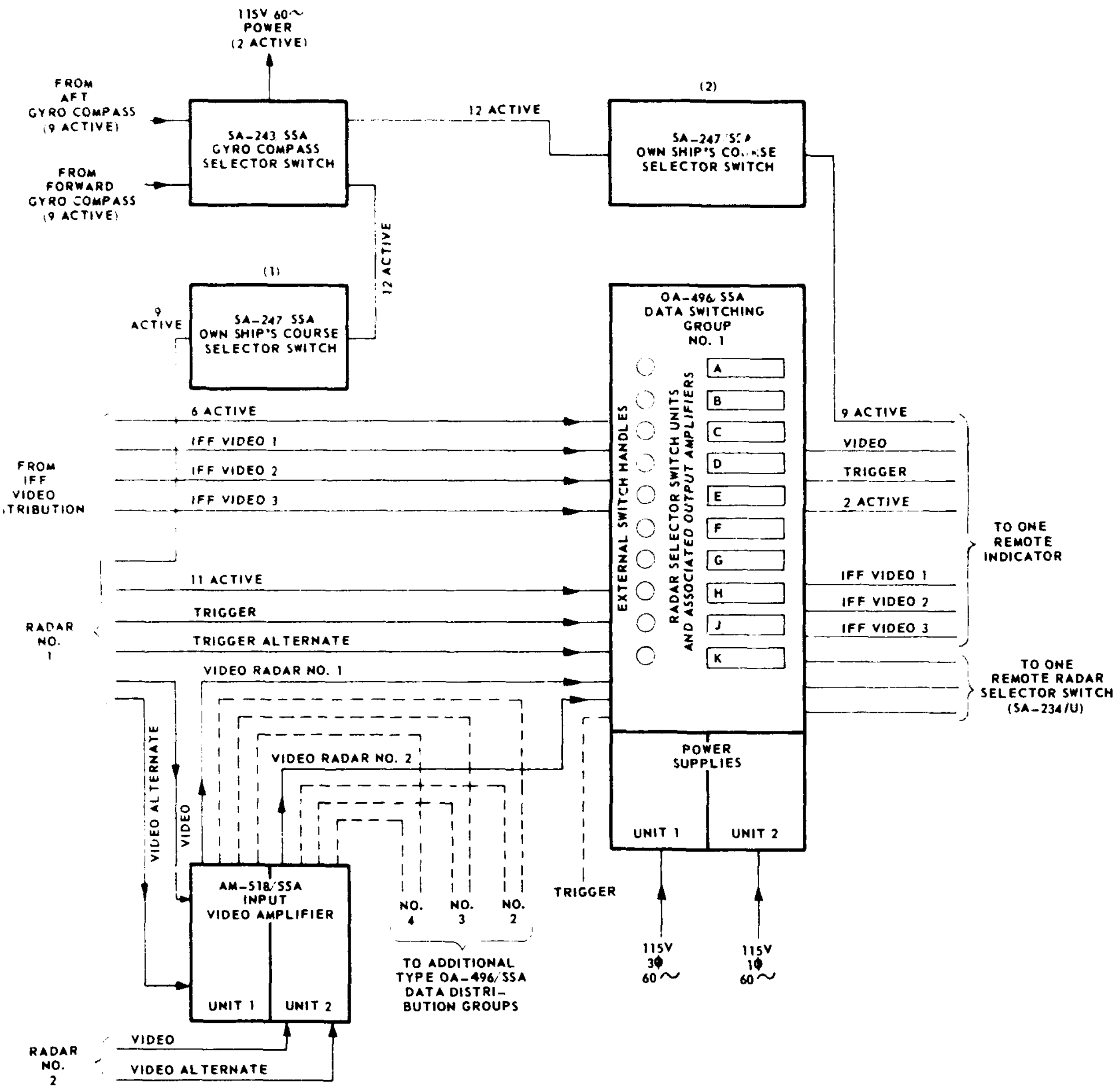

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Figure 8-23.—Block diagram of data switching group OA-496/SSA, and associated units.

one of ten remote radar repeaters. The assembly data switching group consists of 10 radar selector switches (A through K), 10 video and trigger cathode follower subassemblies, and 2 power supplies.

Each selector switch has 25 data sections (decks), the 8 positions (7 active positions; the eighth is OFF) of which are selected automatically by a commutator-type switch used in connection with the remote-control servosystem. The switch may be manually operated locally by means of the external switch handle or remotely by means of the remote selector switches. Each switch section has seven input circuit contacts and one output contact from the common arm.

A 3-section video and trigger switch is installed on the back end of the 25-section switch.

Video signals from the radar receivers are fed through Video Amplifier Assembly AM-518/SSA to the data switching group. This amplifier is capable of providing an essentially flat frequency response for any input signal over a range from 100 cycles through 10 mc. The assembly consists of two amplifiers, each providing for one regular and one alternate input, and four outputs so that the input signal may be delivered to four data switching groups, (one is shown in figure 8-23).

Trigger voltages and IFF video signals are fed directly to the data switching group where they are distributed to the desired remote location.

SWITCHING-CONTROL SERVOSYSTEM

A simplified schematic diagram of the switching-control servosystem is shown in figure 8-24. The system consists of a 3-phase motor, which drives the 8-position, rotary type switch through a gear train; and a split phase motor, which controls the operation and direction of rotation of the 3-phase motor by means of switch S502.

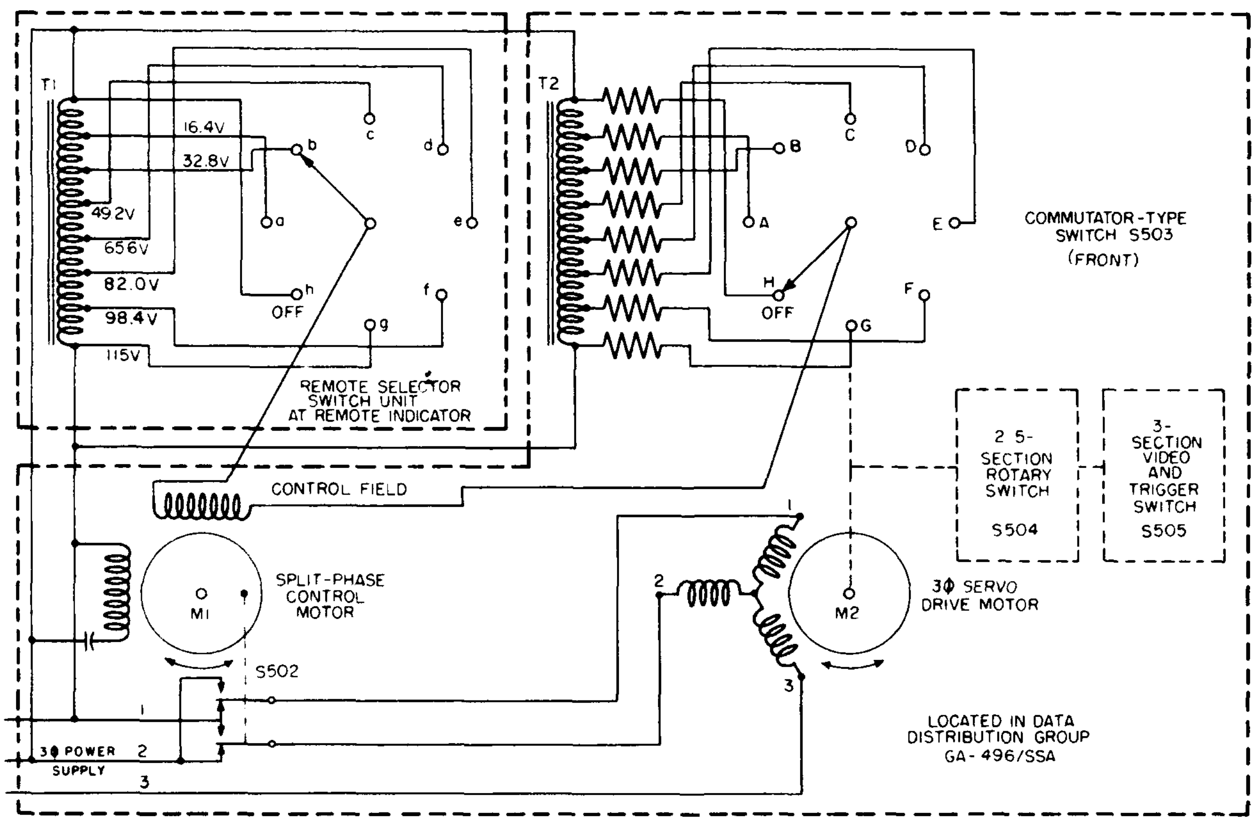

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Figure 8-24.—Switching-control servo system.

Two multitapped, single-phase autotransformers, one in the data switch selector servo unit and one in the remote selector switch unit, provide the required control power to the split-phase motor. These transformers are energized from 1 phase of the 3-phase supply. At the remote selector switch unit, the operator turns the switch to the position that will bring in the desired radar information. The transformer in the switch unit develops an opposing voltage to that developed by the transformer in the servo unit. The voltage contributed by the transformer in the servo unit is zero when S503 is in the H, or OFF position. The potential difference (the potential not balanced out by the action of the two transformers) is applied to the control winding of the split-phase motor and causes it to develop a torque in one direction or the other, depending on the condition of unbalance. A vane on the shaft of the control motor actuates the sensitive switches, S502 (upward or downward against spring action), depending upon the direction in which the torque is developed. The switches apply 3-phase power to the 3 windings of the 3-phase drive motor. The drive motor, M2, drives S503 to zero the voltage on the control field of M1, thereby removing the torque developed by M1 and opening S502 to stop the drive motor.

The drive motor is reversed by reversing the torque on M1 to operate S502 in the opposite direction. This action interchanges two line leads to M2 to reverse its direction of rotation. The reversal of torque on M1 is brought about by the reversal of the control field of M1 with respect to the constant field of M1. The relative phase of the control field depends upon the relative magnitudes of the voltages at T1 and T2 that are applied to the control field.

The 3-phase drive motor drives the commutator switch, S503; the 25-section rotary switch, S504; and the 3-section video and trigger switch, S505. As the commutator switch arm contacts the tap that corresponds to the one selected at the remote selector switch unit, the unbalanced potential is reduced to zero. The control field of the control motor is then deenergized, switch S502 returns to the neutral position, the drive motor is deenergized, and the switch arm of S503 remains in the desired position. The 25-section rotary switch and the 3-section video and trigger switch, on the same shaft with S503, remain in the desired position also.

Rotation of the commutator switch in the opposite direction is accomplished in the same manner, except that the polarity of the unbalanced difference voltage applied to the control field of the control motor is opposite, and the direction of rotation of both motors is opposite.

As an example of automatic operation, assume that the operator at the remote selector switch unit (located at a repeater) desires to receive radar information that will be available if he moves his switch to position b. Assume also that his switch and the one in the data switching group are in the OFF position.

The operator turns his switch to position b, and a potential of 32.8 v developed by T1 is applied to the control field. The opposing voltage in T2 is zero. The control motor turns (for example, clockwise) because of the phase relationship of the control and the constant fields. The motion of the control motor moves S502 downward (for example) and applies phase 1 to terminal 1 and phase 2 to terminal 2 of the 3-phase drive motor. The drive motor rotates switch S503 through position A. The 16.4 v developed by T2 at position A opposes the 32.8 v developed by T1, but a net potential difference of 16.4 v is still applied to the control field of M1. Motor M1 continues to rotate clockwise and M2 moves the contact of S503 to position B. In this position, the voltages developed by T1 and T2 are equal and opposite and no voltage is applied to the control field of M1. Motor M1 stops, S502 springs open, power is removed from M2, and the contact of S503 remains in position B.

The example just given applies to all cases where the remote controller calls for higher position in the alphabet than the initial position of the setting at the data switching group.

For the opposite case, where the remote controller calls for a dial setting lower in the alphabet than the one at the data switching group, a similar analysis will show that the unbalanced control field voltage will produce a current opposite in direction to that of the example given. This results from the fact that the higher voltage now comes from the taps on T2. Accordingly, S502 will be moved upward by the movement of M1 in a counterclockwise direction because of the reversal in phase of the control field with respect to the constant field. Phase 2 will be applied to terminal 1 of the drive motor M1 and phase 1 of the line to terminal 2 of M2, and the contact arm of S503 will be rotated in a direction opposite to

that given in the previous example. Again, when the two voltages (from T1 and T2) are equal, the switch positions are matched and both motors stop.

GYROCOMPASS SELECTOR SWITCH

The Gyrocompass Selector Switch, SA-243/SSA (fig. 8-25) is used to select either the forward or aft gyrocompass synchro output (both 1X and 36X speed) and to provide a 78-v synchro electrical zero reference voltage. The switch consists of a 20-pole, 3-position type switch controlled by a relay. Electrical zero reference voltage is provided by autotransformer T701 when the switch is turned to either the forward or aft gyro position. In case of a power failure of the selected gyro source, relay K701 (A and B) is deenergized, providing a signal from the alternate source. Indicator lights inform the operator which gyro output is appearing on the switch position selected.

OWN SHIP'S COURSE SELECTOR SWITCH

This switch (fig. 8-26) is capable of selecting either a gyro output signal (from the fore or aft gyro, as selected by the gyrocompass selector switch) or the electrical zero reference voltage from the rotary gyrocompass selector switch.

A relay in the unit automatically selects the electrical zero supply voltage and applies it to the synchro in the repeater on failure of the gyro output from the gyrocompass selector switch. A flashing light on the front of the own ship's course selector switch indicates gyro failure.

RADAR SELECTOR SWITCHES

The ten 25-section switches (one of which is shown as S504 in fig. 8-27) in the data switching group, transfer the incoming information (except video and trigger) from any one of the seven radars and the information from the IFF video distribution system to any or all of the 10 remote indicators. A wiring diagram of a typical radar selector switch is shown in figure 8-27. Each switch includes two units, S504 and S505. Unit S504 has 25 data sections and 8 positions referred to previously in the introduction to the distribution of radar information.

Unit S505 has three sections and eight positions and is mounted on the same shaft as S504. Both S504 and S505 turn as a single unit and may be operated by an external handle or automatically by a servo unit, as previously described. The video and trigger signals are fed into S505 from the input terminal group, indicated as a block in figure 8-27.

TRIGGER AND VIDEO SWITCHING.—Trigger and video signals from the various radars (up to seven) connected to the switching group are fed to the input terminal group. From the input terminal group, trigger voltages are fed to seven sections of deck section 1 of S505. Video signals from the seven radars are likewise fed to seven sections of deck section 3. Deck section 2 serves as ground.

Although only one switch (made up of S504 and S505) is shown in figure 8-27, it should be recalled that 10 of these switches are wired into the system.

For example, assume that after being amplified in video amplifier AM-518/SSA, the video signal from radar 1 is fed through the input terminal group to switch terminal 1-80 of S505 (fig. 8-27). The same signal is also fed to terminals 1-80 of S505 in the nine remaining switches. The outputs (from terminal 180) of the 10 switches are fed independently through the output amplifier associated with each switch to the repeater associated with each amplifier. Any or all of the repeaters may be switched to radar 1. The radars connected to the other terminals of the radar selector switch may likewise be selected at the repeater.

Trigger switching follows the same general pattern as video switching, except that the trigger voltage is not amplified before it is fed to the input of the data switching group.

The detailed connections of one switch unit are shown in figure 8-28.

SWITCHING OF IFF AND OTHER DATA.—Whereas S505 handles video and trigger switching, S504 handles such additional data as antenna bearing, relative bearing IFF video signals, IFF control functions, etc.

The various circuits feeding into and out of a typical switch (S504) are illustrated in figure 8-29. The type of data passing through the various terminals are written on the terminals to simplify signal tracing. The parallel nature

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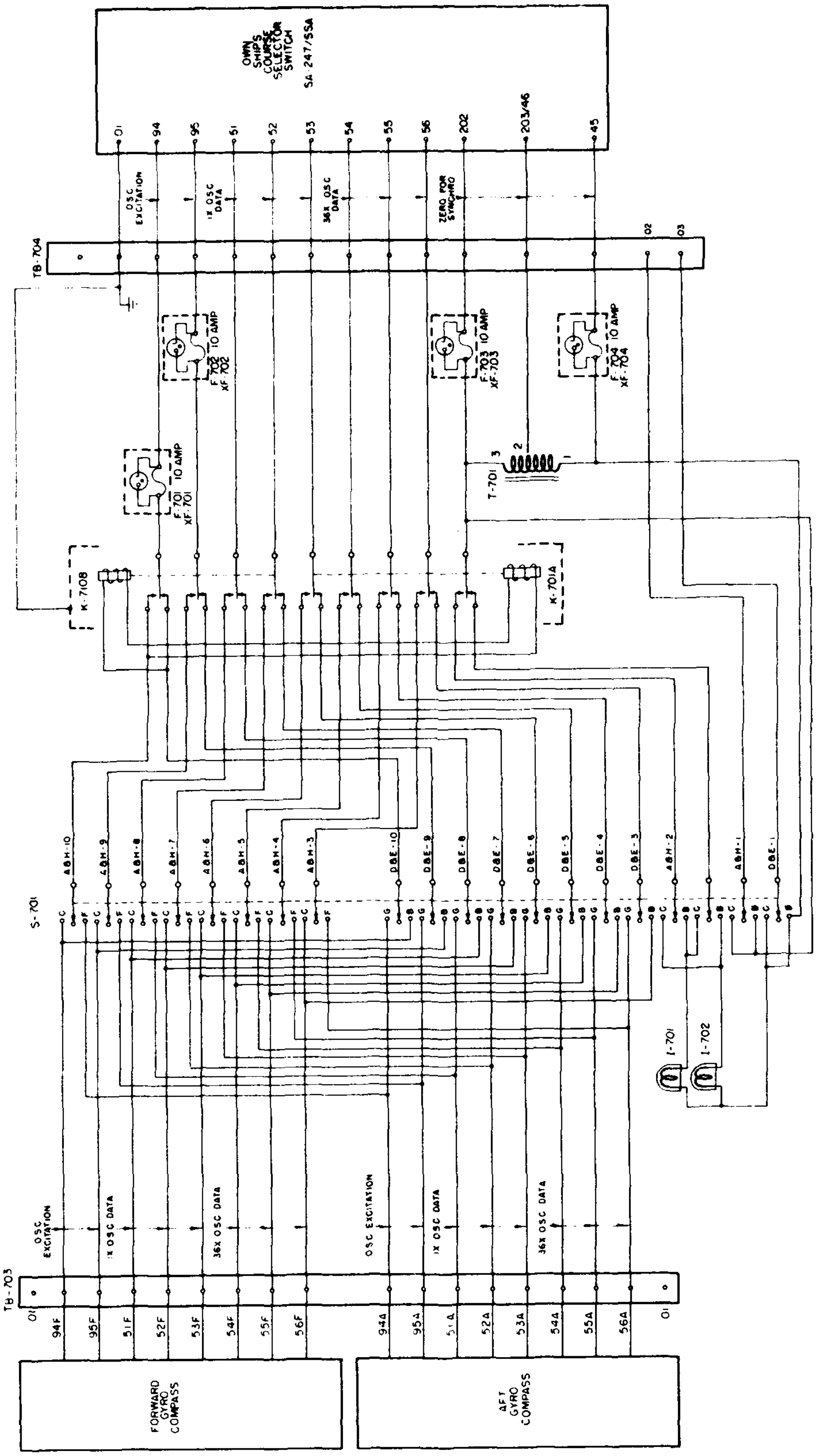

Figure 8-25.—Gyrocompass selector switch.

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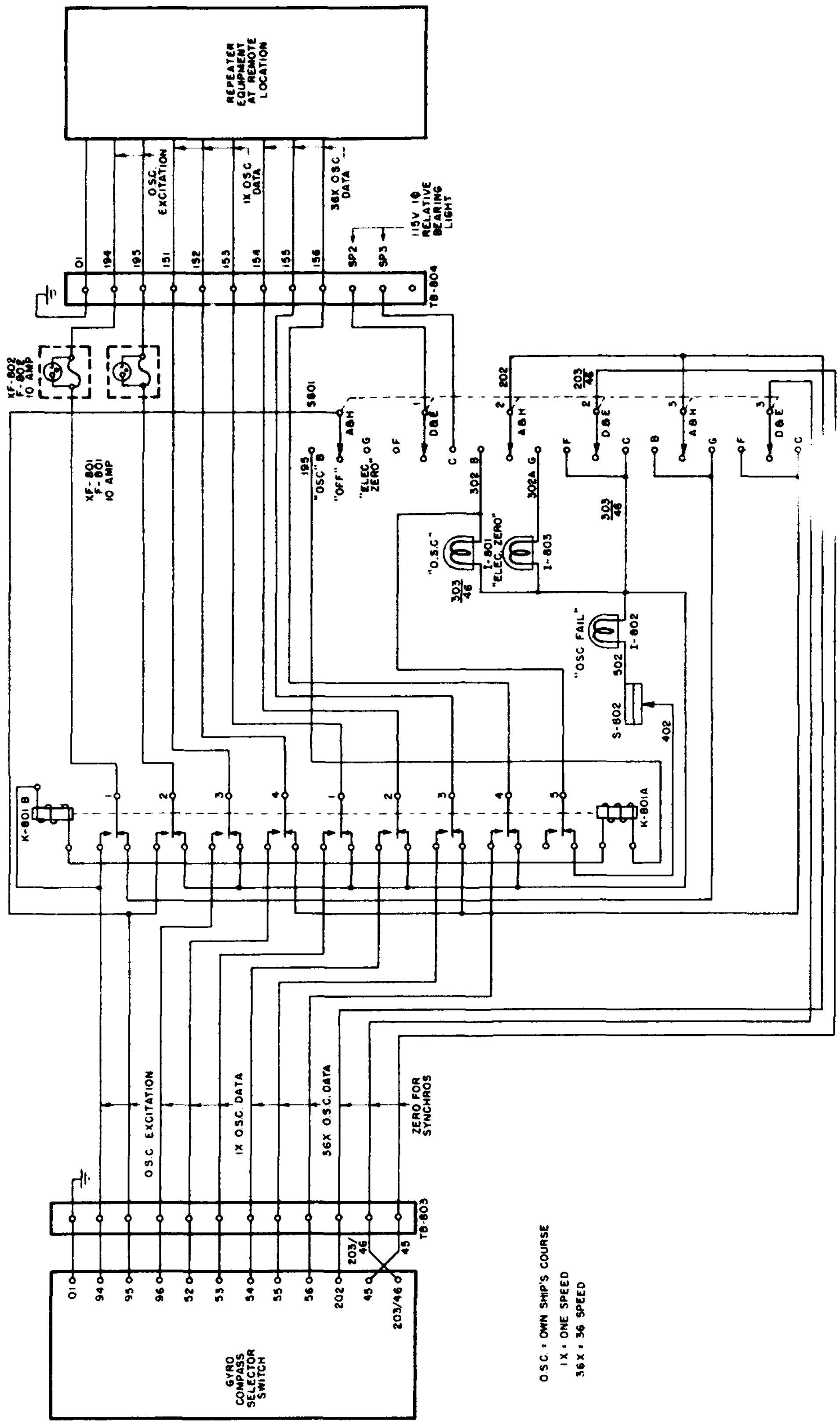

Figure 8-26.—Own ship's course selector switch.

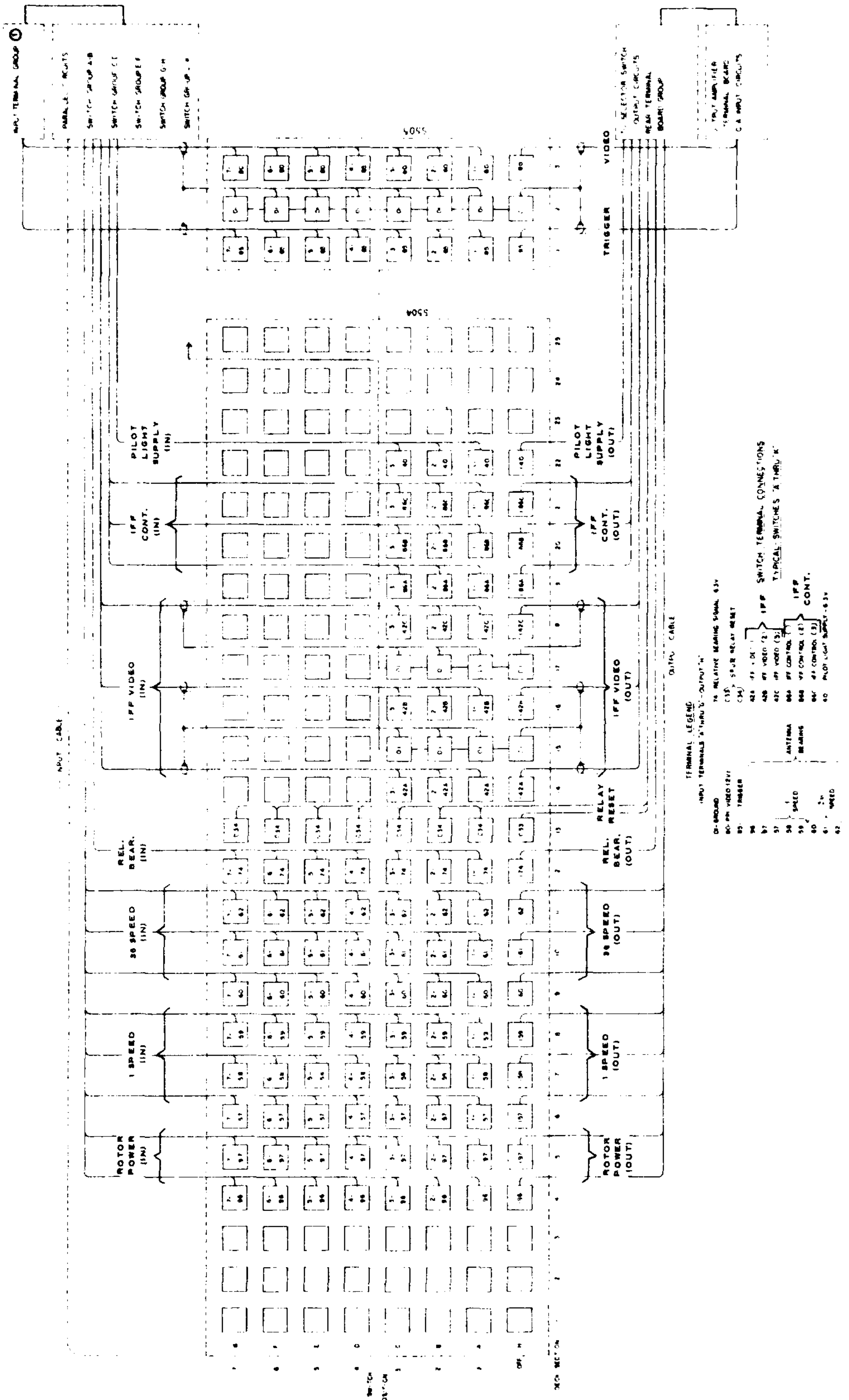

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Figure 8-27.—Radar selector switch in the data switching group.

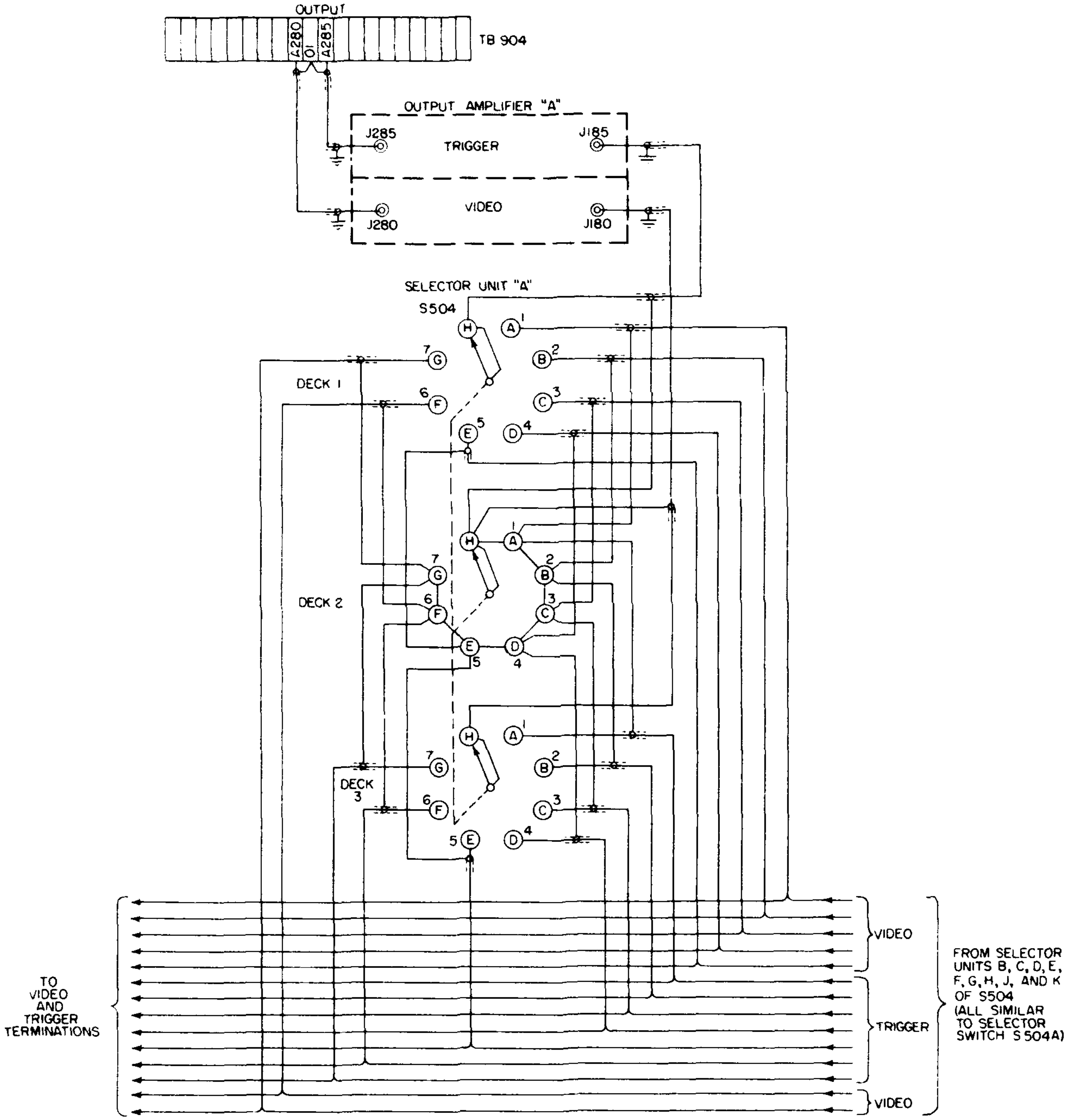

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Figure 8-28.—Wiring diagram of video and trigger switching circuits.

of the circuit connections should be kept in mind, and the same reasoning that was employed in video and trigger switching may be employed here.

The paralleling of switch contacts bearing the same information in the 10 switches is accomplished in the parallel circuits section of the switching group.

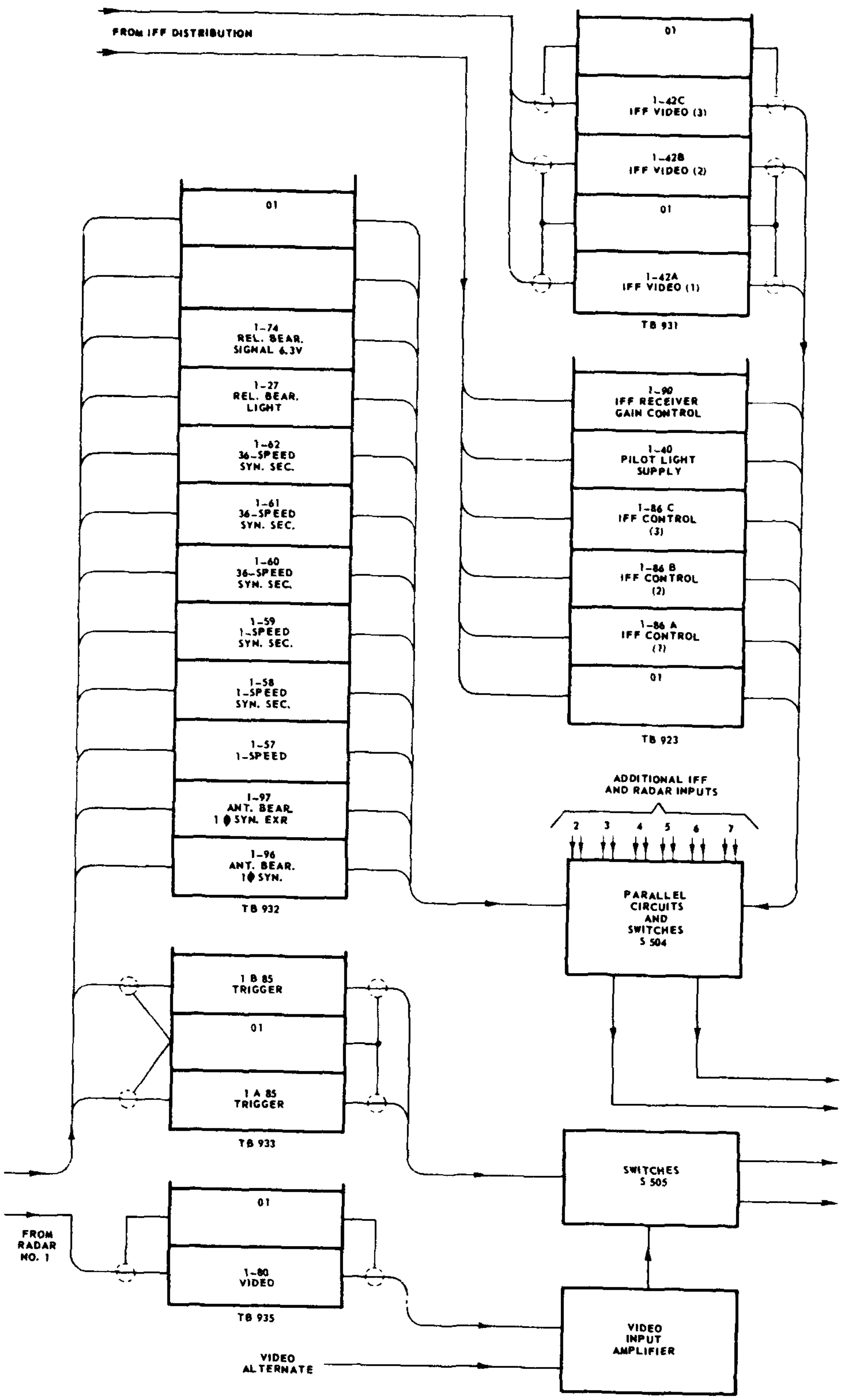

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Figure 8-29.—Diagram showing route of signals from radar to repeater through the radar switchboard—Continued.

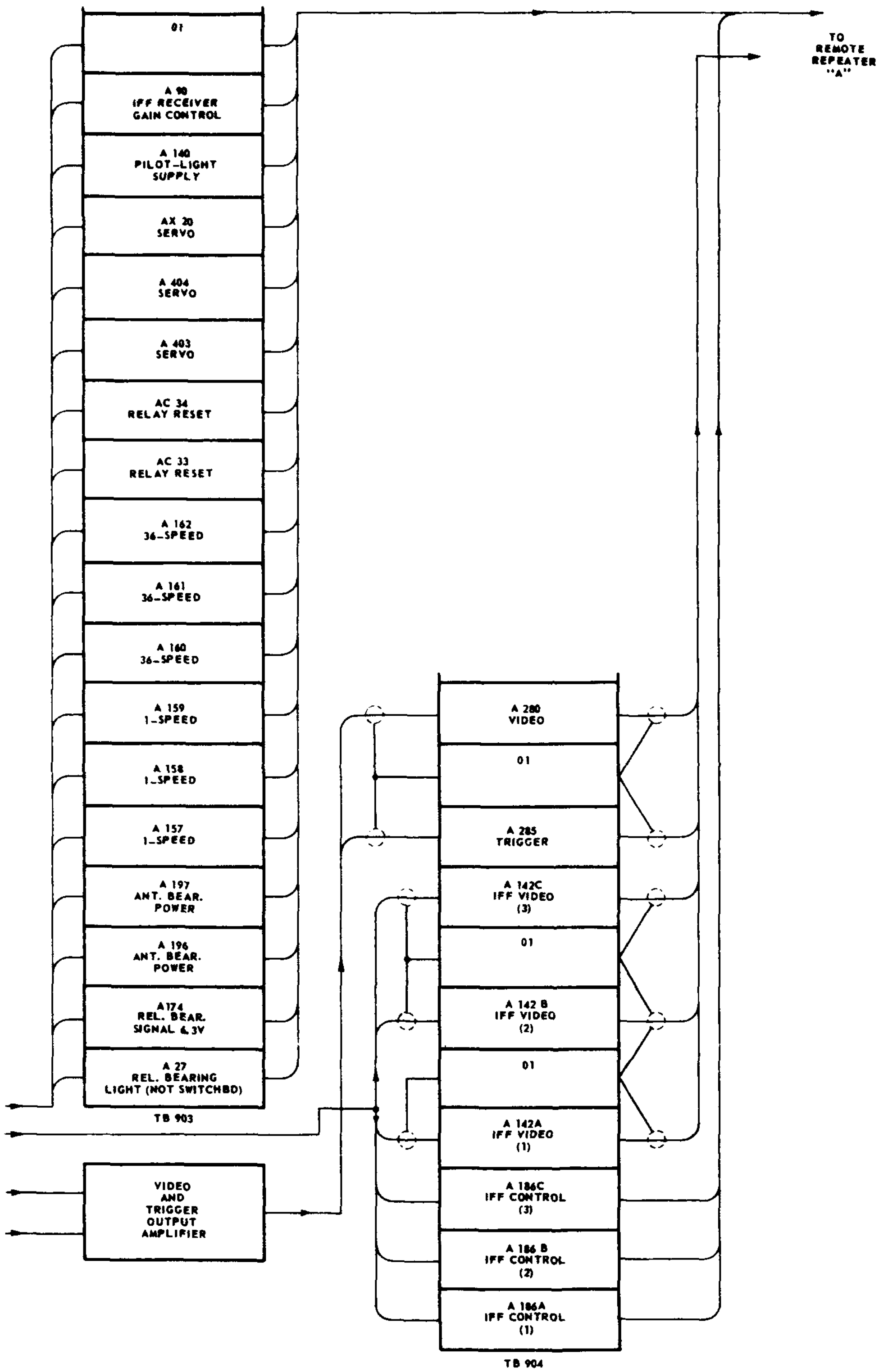

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Figure 8-29. –Diagram showing route of signals from radar to repeater through the radar switchboard–Continued.

CHAPTER 9

COMMON OPERATING ADJUSTMENTS: RADIO TRANSMITTERS AND RECEIVERS

The ET 3 must know how to make many operating adjustments on a variety of electronic equipments. These equipments include communications transmitters and receivers (and associated TTY and FAX circuits), surface search and height finding radars and their associated repeaters (including IFF equipment), and electronic aids to navigation. Common operating adjustments include starting and stopping the equipment, tuning it, and selecting the operating frequency. Meter readings of current, voltage, and power must be taken; gain-control or intensity-control adjustments must also be made. The knowledge of how to perform these functions is basic to his knowledge of maintenance and repair because without it the ET 3 can do little to maintain or repair an equipment.

The common operating adjustments are made by means of external controls. Other chapters in this training course describe various electronic circuits associated with external controls and analyze their functions. The purpose of this and the following two chapters is to describe the common operating adjustments for radio, loran, teletype, facsimile, and radar equipments.

RADIO TRANSMITTING SET AN/SRT–15

First, consider the Radio Communications Transmitting Set AN/SRT-15 (fig. 9-1). A general description of the major components is followed by a discussion of some of the common adjustments.

The set may transmit an r-f carrier at either a 100-watt or a 500-watt nominal level. The r-f carrier may be amplitude modulated for radiophone (type A3 emission), or it may be ON-OFF c-w telegraphy (type A1 emission), either hand or machine keyed. Other modes of operation include telegraphy by frequency-shift keying (type F1 emission), using an FS machine key (teletype operation), and facsimile (type F4 emission), using frequency modulation.

Frequency selection is manually accomplished. A set of nine frequency selection control knobs located on the radio frequency oscillator provides a range of frequencies from 0.3 mc to 26 mc in 10-cycle steps.

Start-stop control, keying, and radiophone may be obtained from a remote location. Standard Navy six-wire radio transmitter control circuits are used for all remote-control operations.

The AN/SRT-15 with all accessories includes a 100-watt transmitter group and booster, antenna tuning equipment, antenna, and remote radiophone unit. The booster includes modulator-power units to accomplish 500-watt operation. The transmitter bay consists of the 100-watt transmitter group, a transmitter coupler, two mountings, and the radio modulator-power supply (booster).

The antenna tuning equipment includes an antenna coupler and r-f tuner.

The 100-watt transmitter group contains all circuits for generating the desired radio frequency and amplifying it to the 100-watt carrier level, and provides it either in amplitude or frequency-modulation communication, as previously described. The modulated r-f carrier output is fed through a 50-ohm coaxial cable to an adjustable autotransformer (transmitter coupler) for matching the output of the radio frequency amplifier to the input of the antenna coupler.

The transmitter group includes a cabinet holding five pull-out drawer-type chassis. From top to bottom these units are (1) the radio frequency amplifier (RFA), (2) the low-level radio modulator (LLRM), (3) the radio frequency oscillator (RFO), (4) the low-voltage power supply (LVPS), and (5) the medium-voltage power supply (MVPS).

The functional block diagram of Radio Transmitting Set AN/SRT-15 is shown in figure 9-2.

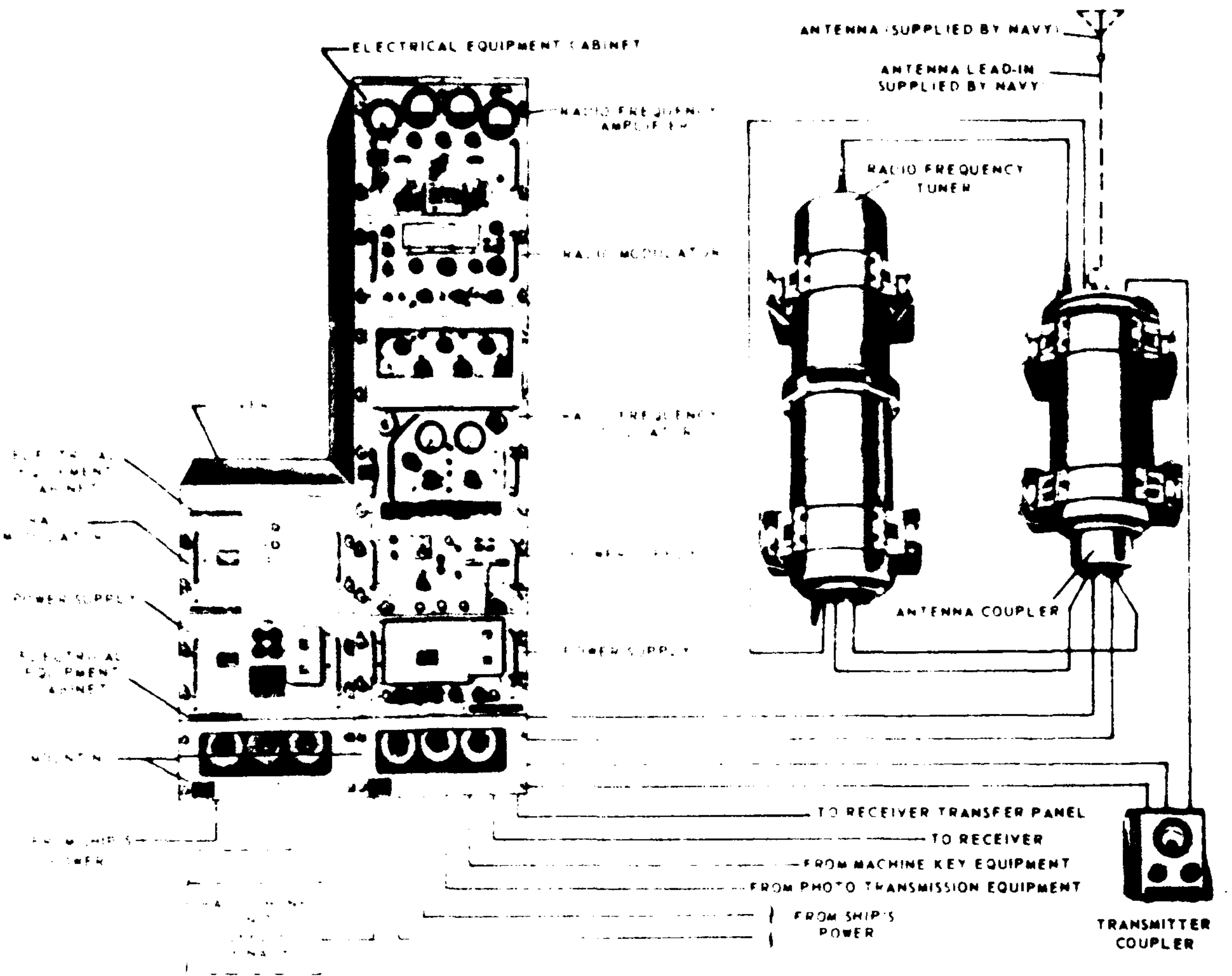

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Figure 9-1.—Radio transmitting set AN/SRT-15.

The r-f Carrier originates in the radio frequency oscillator and is amplified in the radio frequency amplifier. The output of the radio frequency amplifier is fed to the antenna via the load adjusting unit and the antenna coupler. For 100-watt operation the output of the low-level radio modulator is fed directly to the radio frequency amplifier. For 500-watt operation the output of the low-level radio modulator is fed to the high-level radio modulator and the output of the high-level radio modulator is fed to the radio frequency amplifier. The radio modulator power supply (in the booster) provides the necessary additional power to increase the r-f carrier output from 100 to 500 watts.

It should be noted that where references are made to the low-level radio modulator or the high-level radio modulator, they should not be interpreted as meaning the technique of modulation known as grid modulation as opposed to plate modulation, but rather as referring to the operating power level of 100 or 500 watts.

RADIO FREQUENCY AMPLIFIER

The radio frequency amplifier (fig. 9-3) amplifies the r-f signal received from the radio

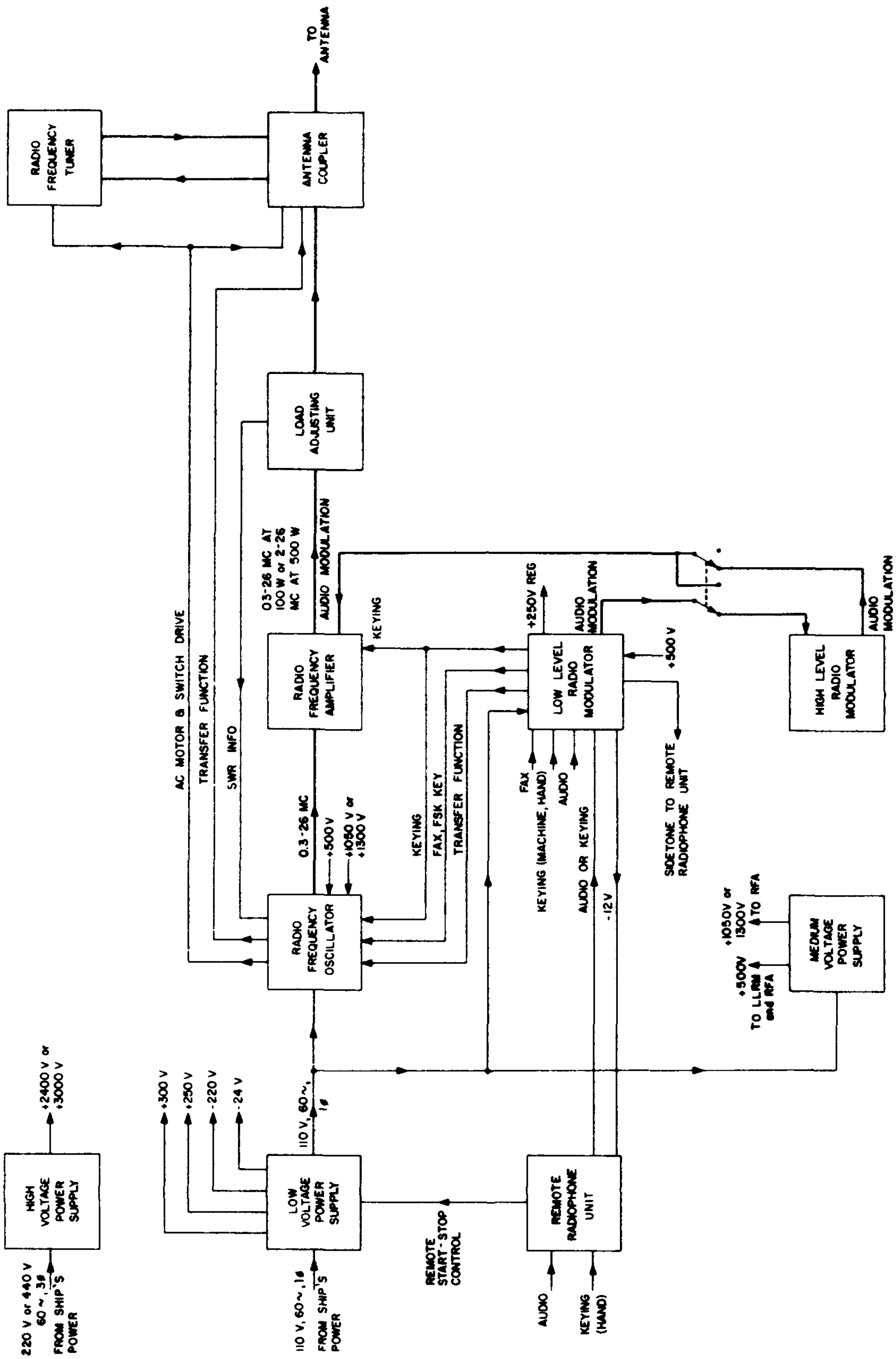

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Figure 9-2. —Block diagram of radio transmitting set AN/SRT-15.

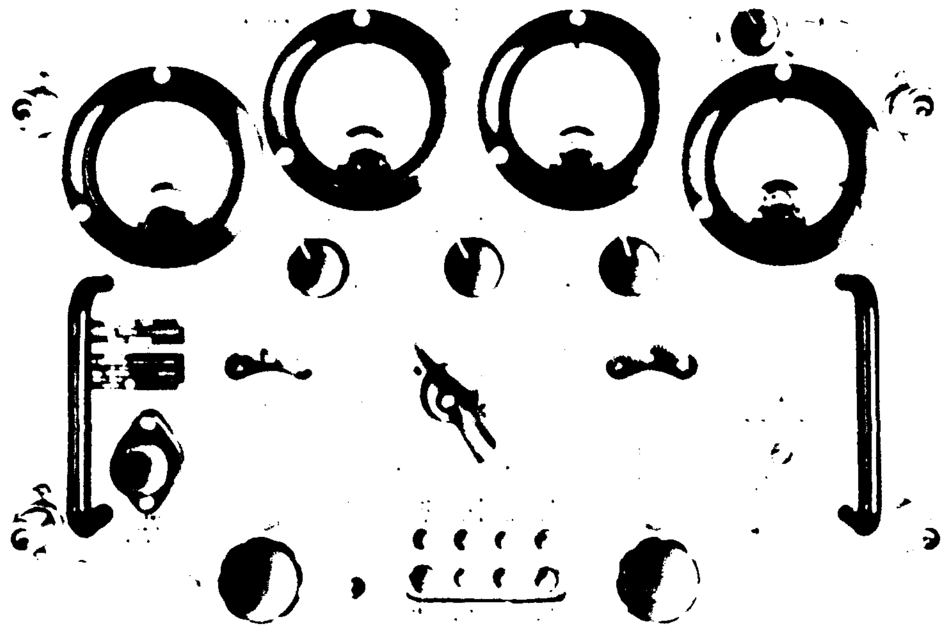

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Figure 9-3.—Radio frequency amplifier AM-1008/SRT.

frequency oscillator to either the 100- or 500-watt nominal level. It consists of three stages of amplification, which include (1) the buffer, (2) the intermediate power amplifier (IPA), and (3) the power amplifier (PA).

The output of the radio frequency oscillator drives the tuned buffer stage. This stage also receives keying signals from the low-level radio modulator to key the output of the RFA ON and OFF during hand-key, machine-key, and phone operation. The tuned IPA stage, which follows, uses a beam power tetrode.

The final stage is the power amplifier, employing a tetrode with forced-air cooling. In phone operation, an audio modulating signal is received from either the low-level radio modulator (100-watt operation) or the high-level radio modulator (500-watt operation) to amplitude modulate the output of the RFA.

The RFA is manually tuned by the adjusting of three front-panel controls (the band switch, the tune IPA control, and the tune PA control). In both the IPA and the PA stages of amplification there is a tuned plate tank circuit that is affected by these controls. The first of the tuning controls is a six-position band switch that connects a tank circuit to each of the three stages in accordance with the band of frequencies in which the selected transmission frequencies lie. The second control tunes the buffer and IPA stage tank circuits and the third control tunes the PA stage. The second and third controls vary the capacity of the tank circuits to bring them into resonance at the desired frequency.

In addition to the tuning controls, there is a control (excitation control) for regulating the input level of the signal from the radio frequency oscillator. The RFA front panel contains four meters used for tuning indicators and as test meters for various operating voltages and currents. A set of indicator lamps is provided to indicate overload conditions and operating conditions of the carrier.

A pushbutton switch, which is used to place the set in nominal 500-watt operation, is mounted on the RFA front panel. A second pushbutton is used to restore the set to the 100-watt level.

LOW-LEVEL RADIO MODULATOR

The low-level Radio Modulator MD-229/SRT is illustrated in figure 9-4. This unit accepts

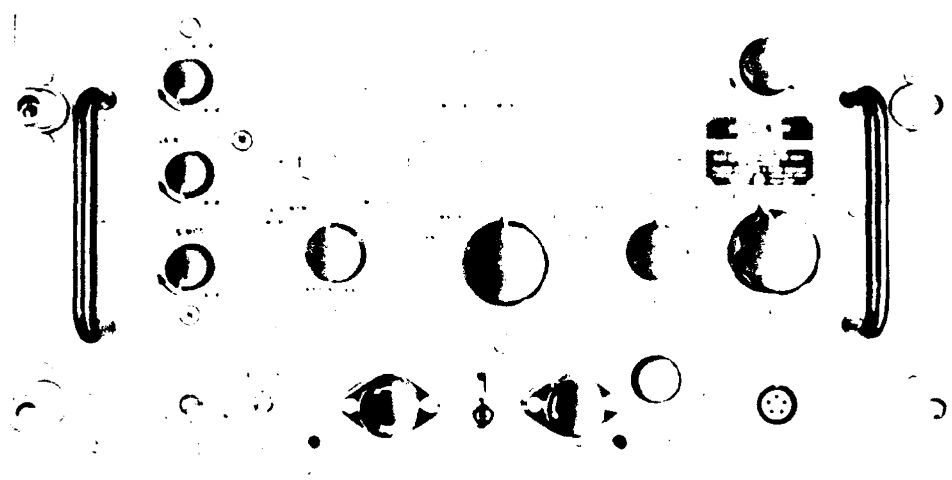


Figure 9-4.—Radio modulator MD-229/SRT (low level modulator LLRM). 1.147

voice, telegraphy (hand or machine key), frequency shift (teletype), or facsimile signals. It contains audio-amplifying and modulating circuits for amplitude modulation of the r-f carrier at the 100-watt level. For 500-watt operation the low-level radio modulator feeds the high-level radio modulator (HLRM) that boosts the signal to the required level. Peak limiting and noise suppression (squelch) circuits are provided in the audio circuits. Either carbon or dynamic microphones may be used.

An electronic keyer circuit provides the keying voltage to control the radio frequency amplifier during c-w telegraph (hand-key and machine-key operation) and to control the radio frequency oscillator in frequency—shift telegraphy. The keying circuits are suitable for speeds from hand keying to 600 words per minute. Facsimile signals are connected through the low-level radio modulator to the frequency-shift circuits in the radio-frequency oscillator drawer. An audio oscillator (200-cycle output) is included in the LLRM to phase-modulate the transmitter signal to overcome selective fading in frequency-shift transmission; in c-w telegraphy the oscillator has a 100-cycle output used for aural monitoring of the keying signals.

The front panel of the LLRM has controls for selecting the mode of transmission, receptacles for a local carbon or dynamic microphone, gain controls, and a squelch circuit control. A test key is provided for carrier control.

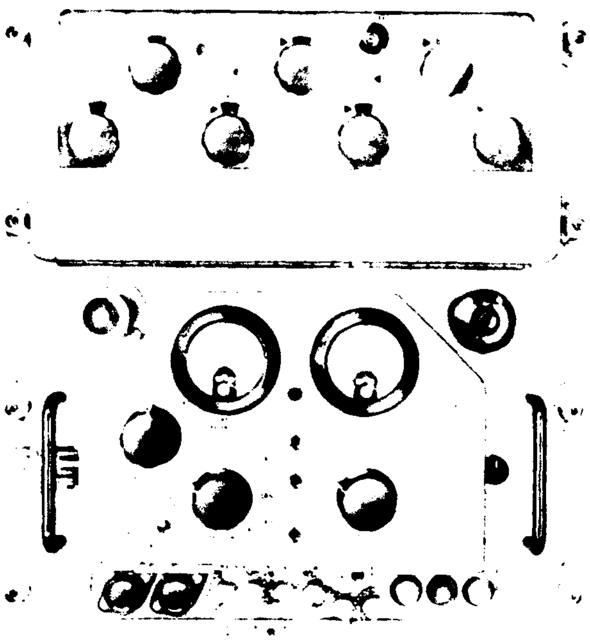
RADIO FREQUENCY OSCILLATOR

The radio frequency oscillator (Fig. 9-5) is the source of the r-f carrier signal. It consists of 15 sections: 14 removable units (holding the electron tube circuits) and a mounting to which these units are attached. The 15 sections have official standard item name and symbol designations but are usually referred to by their common name or unit number.

The output stage of the RFO is divided into three separate units (11a, 11b, and 11c) each of which covers a portion of the total frequency range of the radio transmitter.

Units 1 through 12 are equipped with multiple pin-type connectors that mate with receptacles on unit 14. Radio-frequency connections are made through connectors and jumper cables. On each subchassis, test points are provided at r-f input or output points. By using a test cable, any subunit can be examined in detail with each part readily accessible.

There are three individual oscillators in the RFO. Unit 1 is the crystal oscillator, which generates the basic frequency of 100 kc with an accuracy of 1.5 parts per million over the temperature range of -4°F to +122°F. Unit 3 is the interpolation oscillator used to obtain the 10-cycle steps. Unit 12 is the frequency-shift oscillator. The 100-kc carrier frequency of this oscillator is capable of being shifted from



1.148

Figure 9-5.—Radio frequency oscillator O-275/SRT(RFO).

+2000 to -500 cycles about the 100-kc value. The frequency-shift oscillator is used in the mixing sequence only when service selector control, U, on the LLRM (fig. 9-4) is set in one of the frequency-shift positions, FSK or FAX.

The 100-kc signal from the crystal oscillator controls several frequency multipliers that generate a high order of frequencies for the mixing stages. Locked to the crystal oscillator are 10-kc, 100-kc, and 1-mc step generators, each of which provides 10 frequency increments used in the mixing sequence. The independent interpolation oscillator is used to obtain 10-, 100-, and 1000-cycle steps. This interpolation can be checked readily against the crystal oscillator and may be adjusted to maintain its accuracy. Several frequency converters mix the signals from the crystal oscillator, interpolation oscillator, and step generators to provide an r-f signal in steps of 10 cycles over the frequency range of 0.3 to 26 mc.

The front panel of the RFO (fig. 9-5) has all the controls for setting up any frequency within the frequency range. Nine knobs are provided for manually setting a frequency. An electron-ray tube is provided for checking the frequency-shift oscillator or the interpolation oscillator against the standard crystal oscillator. A set of test receptacles is provided on the front panel; these bring out important signals in the RFO for monitoring with a standard test oscilloscope.

The Antenna Control Indicator C-1352/SRT is mounted on the face of the FRO front panel and is considered as a component of the RFO. The control indicator has all the controls and indicators required to accomplish the manual tuning of the antenna coupler and r-f tuner.

A set of three pushbutton switches controls the UP and DOWN movement of the shorting ring on the main tuning coil in the r-f tuner. One toggle switch is used to control the action of the bypass switch in the antenna coupler, enabling the antenna tuning equipment to be placed in the antenna line or to be completely bypassed. One rotary switch controls the loading switches in the antenna coupler, selecting various values of capacitive or inductive reactance loading in conjunction with the main tuning coil. Another rotary switch controls the action of a switch in the r-f tuner, which switches an impedance-matching transformer in or out of the transmission line. An indicator is provided to show the standing-wave ratio on the transmission line. The indicator has an associated switch that is used to set the range of the indicator. A second indicator shows the position of the shorting ring on the main tuning coil in the r-f tuner.

LOW-VOLTAGE POWER SUPPLY

Power Supply Unit PP-1094/SRT (fig. 9-6) is commonly called the low-voltage power supply (LVPS) to distinguish it from other power supplies in the transmitting set. It includes three conventional full-wave rectifiers employing electron tubes and the associated filter circuits. A metallic full-wave rectifier provides a separate -24-volt supply for control circuit functions. One plate-filament transformer supplies all voltages for the rectifier circuits. The primary a-c input is 110 volts, 60 cycle, single phase.

The two controls for turning power on and off in the 100-watt transmitter group are located on the front panel of this unit. A cabinet heater switch controls heaters provided to raise the equipment temperature under some conditions. The standby operate switch may be used to

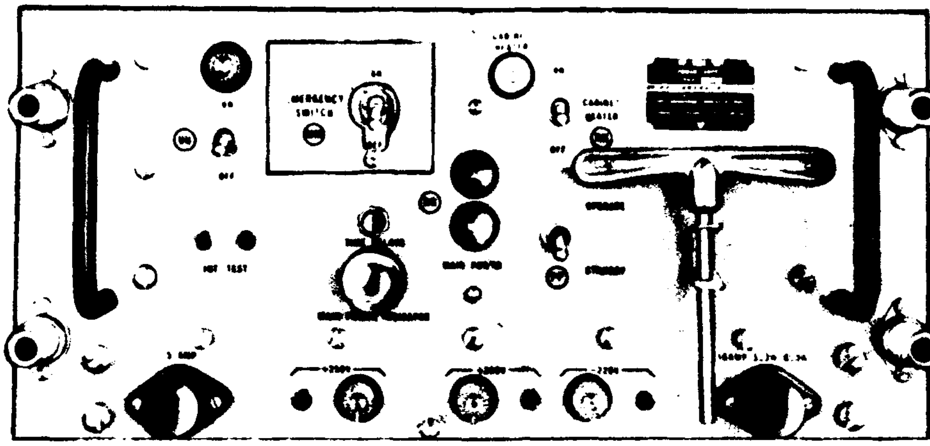


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Figure 9-6.—Low voltage power supply (LVPS) PP-1094/SRT.

put the equipment in a "ready" or "standby" condition. The front panel indicator lights show the proper operation of controls and circuits of this unit.

MEDIUM-VOLTAGE POWER SUPPLY

Power Supply Unit PP-1095/SRT (fig. 9-7) is commonly called the medium-voltage power supply (MVPS). It contains the necessary power transformers, rectifier tubes, filter components, and miscellaneous parts to provide outputs of +500 volts and +1050/1300 volts for the IPA and PA tubes of the RFA and portions of the low-level radio modulator. This unit is energized by operating the appropriate controls on the front panel of the low-voltage power supply. The +500-volt supply is used when the equipment is operating at the 100- and 500-watt levels, but the +1050/1300-volt supply is used only at the 100-watt level. The +1050-volt output is used with phone service only; whereas, the +1300-volt output is used with all other modes of transmission. The elapsed time meters on the front panel are provided for logging transmitter-group tube hours (filament and plate).

TRANSMITTER COUPLER

The load adjusting unit (fig. 9-8) is Transmitter Coupler CU-402/SRT. This unit has a mounting bracket to permit independent mounting. The unit includes an autotransformer with four taps and a standing-wave ratio monitor circuit. An input switch and an output switch, each with four positions that connect to the four taps of the autotransformer, are also components of this unit.

The r-f output of the radio frequency amplifier is connected by interconnecting cabling to the standing-wave ratio monitor and then to the input switch and one of the taps of the autotransformer, which acts as an impedance-matching device. The output from the autotransformer (from the tap selected by the output switch) is fed to the antenna coupler.

RADIO MODULATOR POWER SUPPLY

The Radio Modulator Power Supply OA-685/SRT (booster) (fig. 9-9) provides additional audio and plate power to increase the r-f carrier output of the 100-watt transmitter group to 500 watts. Limitations within the transmitter and antenna tuning equipment make it impracticable to obtain 50-watt carrier operation on the lower frequencies from 0.3 mc to 2 mc. With this exception, all features of the 100-watt transmitter are retained when 500-watt operation is used. Transmitter and antenna tuning is performed at the 100-watt level; high power is applied only when tuning has been completed.

The booster includes (1) Radio Modulator MD-230/SRT (high-level radio modulator) (fig. 9-9 A) and (2) Power Supply PP-1096/SRT (high-voltage power supply) (fig. 9-9, B). The

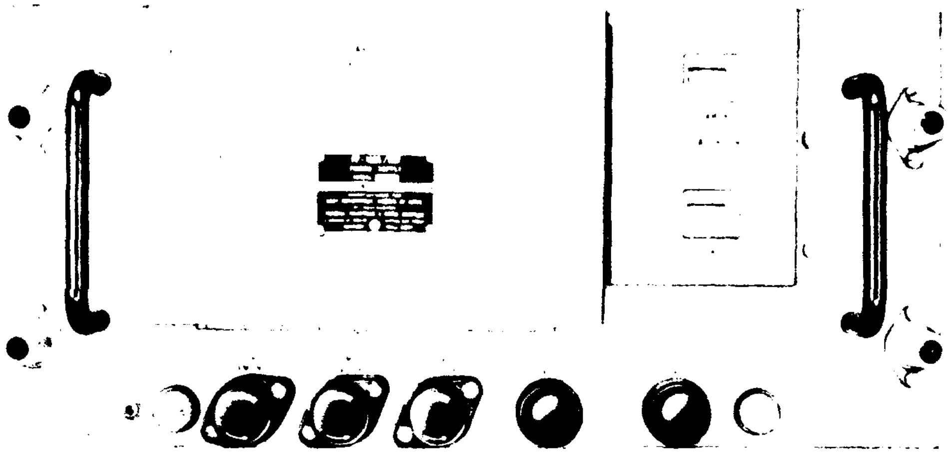

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Figure 9-7.—Medium voltage power supply (MVPS) PP-1095/SRT.

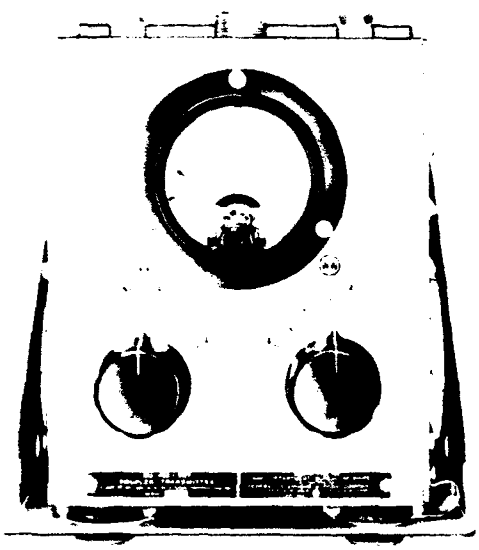

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Figure 9-8.—Transmitter coupler CU-402/SRT (load adjusting unit).

mechanical construction of the booster components is similar to that used in the 100-watt transmitter group. The high-level radio modulator and the high-voltage power supply are of the pull-out drawer design and are housed in individual cabinets equipped with slide and rail arrangement.

The high-level radio modulator (HLRM) modulates the r-f amplifier during phone service at the 500-watt power level. A push-pull, high-level audio power amplifier consisting of two tetrodes operating in class AB2 provides plate modulation for the final r-f amplifier stage. The low-level radio modulator (LLRM) supplies 6 watts of power to drive the HLRM.

The control that energizes the HLRM is located on the RFA front panel.

The high-voltage power supply (HVPS) consists of six hot cathode gas rectifier tubes in a three-phase, full-wave rectifier circuit with choke input filter. It provides an output of either +2400-volt or +300-volt d-c power, as required for the plate of the power amplifier tetrode in the RFA. The +2400-volt output is used for phone service only; whereas, the +3000-volt output is used with all other modes of transmission. By means of links the input connections of the HVPS may be changed to use either 220- or 440-volt, 3-phase, 60-cycle primary power.

An emergency switch on the front panel of the HVPS controls the 3-phase input power. Filament power is applied to the HVPS (and the HLRM) when the booster emergency switch is on. Application of plate power is controlled by a time delay element and a pushbutton

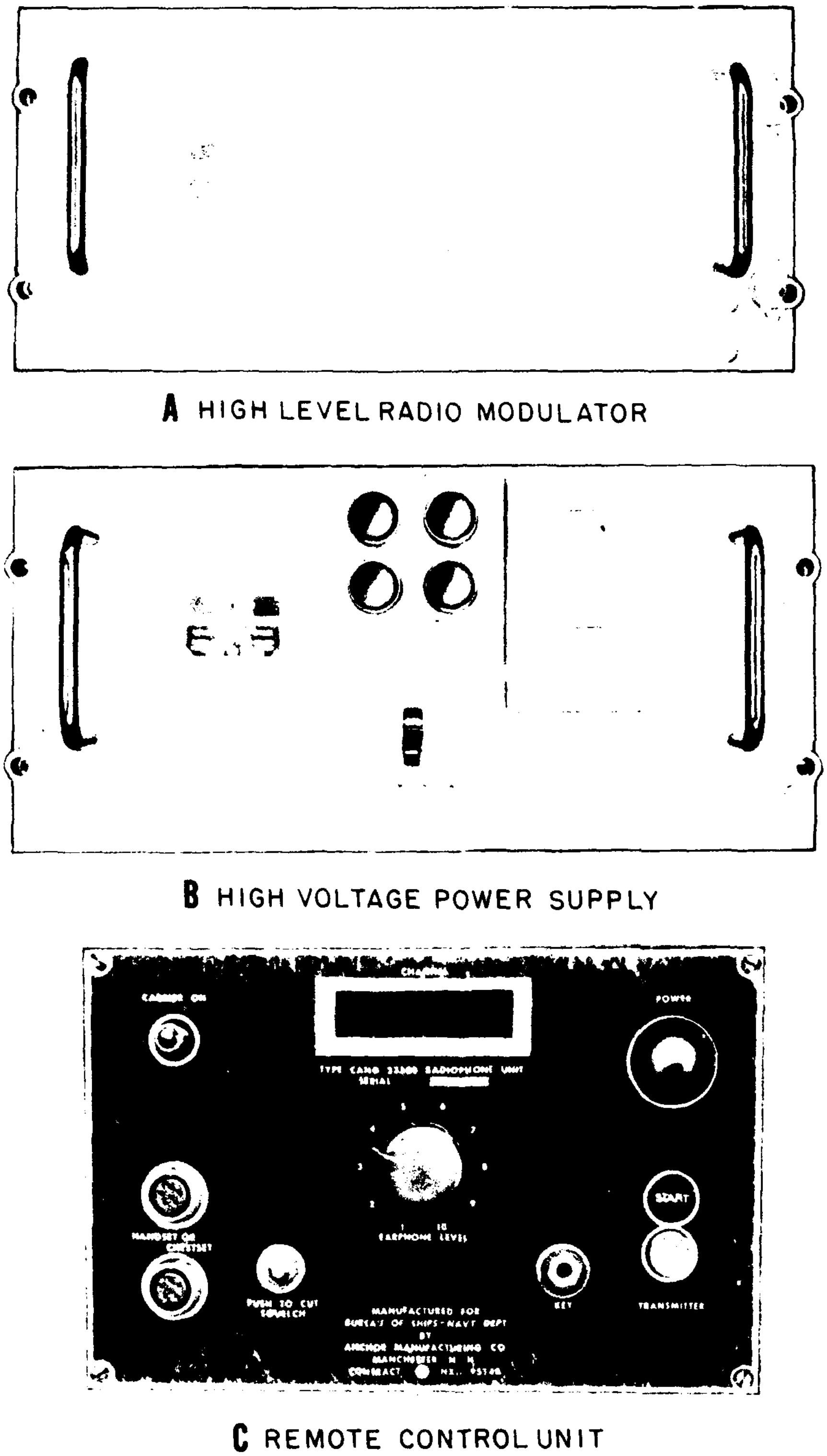

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Figure 9-9.—Radio modulator power supply OA-685/SRT (booster) and radio phone unit type 23500.

switch on the front panel of the RFA. Indicator lights are also provided on the front panel of the HVPS to show power-on and time-delay status.

REMOTE CONTROL UNIT

To operate the transmitting set from a remote location requires a remote-control unit. A typical remote-control unit is Navy type 23500 (fig. 9-9C). This unit contains a start-stop switch for turning the transmitter on or off, jacks for connecting a handset, chest set, or hand key, a volume control for the earphones, and indicator lamps for transmitter-on and carrier-on indications.

R-F TUNER

The function of the antenna tuning equipment (fig. 9-10) is to match the impedance of the r-f transmission line (50 ohms) to the antenna input impedance over the entire frequency range. The principal tuning component to accomplish this match is the main tuning coil found in the r-f tuner. This coil is a helically wound length of transmission line whose length can be varied by the position of a concentric sliding short circuit. A single coupling coil concentric with the main coil is mounted on the sliding short. The sliding short is positioned by a drive motor and associated gear train; the drive motor is controlled from the control indicator mounted on the face of the RFO panel. An impedance matching transformer is also located in the r-f tuner. The transformer can be inserted or removed from the transmission line by a motor-driven switch that, in turn, is controlled at the control indicator. The transformer is required at the low frequencies to match the very low antenna impedance to the 50-ohm transmission line.

A blower is provided for heat dissipation in the r-f tuner. A thermostatic switch that is normally closed and a blower centrifugal switch that is closed only when the blower is rotating are provided as safety devices when the equipment is operated at the 500-watt level. If either or both of these switches are open, the transmitter can function only at the 100-watt level.

The r-f tuner is a sealed moisture-proof unit equipped with valves and a pressure gauge to permit pressurizing the unit to a pressure of 20 pounds per square inch with dry nitrogen gas.

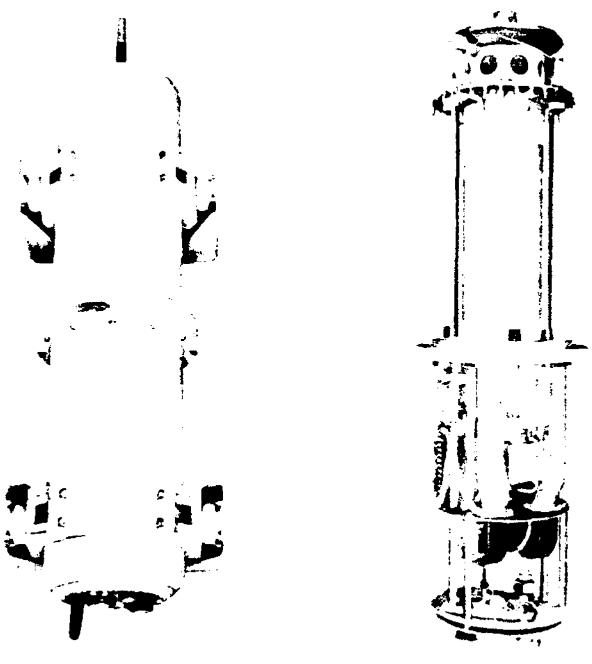

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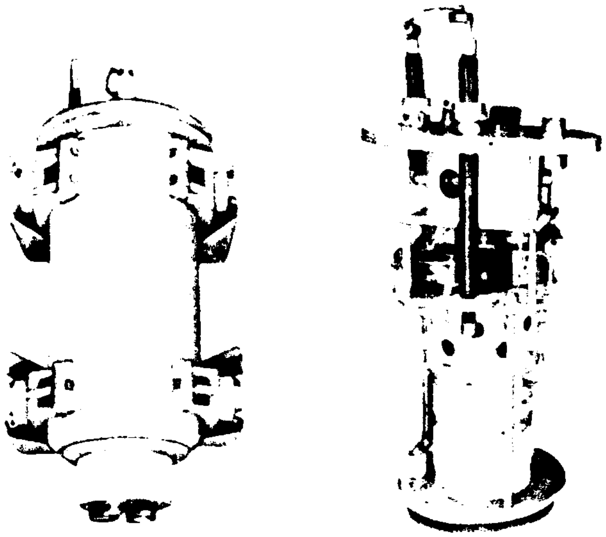
Figure 9-10.—Radio frequency tuner TN-229/SRT (r-f tuner)

ANTENNA COUPLER

The Antenna Coupler CU-372/SRT (fig. 9-11) has two basic functions: (1) to switch various inductive or capacitive reactance components into the transmission line to extend the range of tuning of the main tuning coil, and (2) to provide a switch that permits the antenna to be connected through the tuning components to the transmitter r-f output or to connect the antenna directly to the transmitter r-f output.

To extend the tuning range of the main coil in the r-f tuner, three capacitors and two coils are in the antenna coupler that can be inserted in various combinations in series, or in shunt with the main tuning coil. A motor-driven switch selects the component desired; the switch is controlled from the control-indicator on the front panel of the RFO in the transmitter bay (fig. 9-5). This switch also has a position in which no loading components are added, leaving the main tuning coil in the r-f tuner as the only tuning component in use.



SIDE VIEW, COVER ON

SIDE VIEW, COVER OFF

1.154

Figure 9-11.—Antenna coupler CU-372/SRT.

The switch to either bypass the tuning components or insert them on the transmission line is motor driven. It has two positions and is manually controlled at the control indicator (fig. 9-5).

The antenna coupler, like the r-f tuner, is a sealed unit with similar provisions for charging with dry nitrogen gas.

The transmitting set is designed to work into a 35-foot whip antenna, Navy type C66047, or into a 60 to 130-foot single wire with a 40-foot downlead.

COMMON ADJUSTMENTS

Common adjustments for Radio Transmitting Set AN/SRT-15 include starting and stopping the equipment for 100- and 500-watt operation, selecting the types of service (mode of transmission), selecting a frequency, tuning, and remote operation.

As an example of common operating adjustments, the sequence of operations is given for starting and stopping the equipment for 100- and 500-watt operation.

All the controls for starting and stopping the equipment for 100-watt operation are located on the LVPS (Fig. 9-6).

To start the transmitter for 100-watt operation:

1. Turn the emergency switch, MM, on.
2. Depress the start pushbutton of the main power switch, RR. When the main power is on, the following events take place:
   a. The main power indicator light on the LVPS is energized.
   b. The blower motor in the RFA fig. 9-3 starts to operate.
   c. The -12- and the +250-volt regulated power supplies in the LLRM (fig. 9-4) are energized, and the 250-volt power supply indicator light in the LLRM comes on.
   d. The filament supplies in all units are energized.

Approximately 25 to 30 seconds after the main power is on the following actions occur:

1. The LVPS time delay expires and the time delay indicator light on the LVPS energizes.
2. The +250-v and -220-volt indicator lights on the LVPS are energized, thereby denoting the presence of the corresponding supply voltages.
3. The carrier 100-watt ready indicator on the RFA (Fig. 9-3) energizes.
4. The blower motors in the mounting start operating.

If the standby operate switch, PP, in the LVPS is in the STANDBY position, there will be no plate power and nothing further will happen. Set the standby-operate switch, PP, to OPERATE. If the service selector, U, in the LLRM (fig. 9-4) is set to HAND, the following actions will occur:

1. The +500-volt and the +1050/1300-volt supplies together with the 500-volt primary, 500-volt output, 1300-volt primary, and 1300-volt output indicator lights in the MVPS (fig. 9-7) will energize.
2. The +300-volt indicator light in the LVPS will energize, denoting the presence of this supply voltage.
3. The 100-watt carrier ON indicator light in the RFA (fig. 9-3) will energize.

The actions indicated in items 1 through 2 will occur when the service selector, U (fig. 9-4) is in the MACH, FSK, and FAX positions only if the keying line is closed. If the service selector is in the PHONE position, these actions will occur only when the press-to-talk button on the phone is depressed.

Power in the 100-watt transmitter group may be turned off by depressing the stop pushbutton on the main power switch, RR, on the LVPS (fig. 9-6) or by throwing the

emergency switch, MM, to the OFF position. The latter control removes all power; whereas, the former removes all power except that to the mounting heaters.

The radio modulator power supply (booster) is energized only when it is desired to have the AN/SRT-15 transmitting set operate at the 500-watt level. To energize the booster, the transmitter group must be energized, and the standby operate switch, PP, on the LVPS (fig. 9-6) must be in the STANDBY position. The booster now may be energized as follows:

1. Set the booster emergency switch, SS, on the high-voltage power supply (HVPS) (fig. 9-9B) to ON. After a 30-second time delay, the time delay indicator light is energized.
2. Depress pushbutton E, on the RFA (fig. 9-3) to initiate the following action:
   a. The carrier 500-watt ready indicator light on the RFA will energize. At this time filament power has been applied to the booster but there will be no plate power. The equipment is now in the OPERATE condition. Assume that the service selector, U, in the LLRM (fig. 9-4) is set to the HAND position.
   b. The +1050/+1300-volt supply in the MVPS (fig. 9-7) is deenergized and the 1300-volt primary and 1300-volt output indicator lights in the MVPS will be extinguished.
   c. The O1, O2, and O3 high-voltage primary indicator lights on the HVPS (fig. 9-9B) are energized.
   d. The 3000-volt and 350-volt screen indicator lights on the HLRM (fig. 9-9A) are energized, thereby denoting the presence of these supply voltages.
   e. The carrier 500-volt on indicator in the RFA (fig. 9-3) is energized.

To turn off the booster, depress the disable 500-watt pushbutton, F, on the RFA. This action disables plate power only in the booster. Turning the booster emergency switch, SS, on the HVPS (fig. 9-9B) to OFF removes both filament and plate power in the booster. If the 100-watt transmitter group power is turned off while booster power is still on, plate power will be removed from the booster also.

Figure 9-12 illustrates, by functional block diagrams, the sequence of operation of the control circuits. Figure 9-12A shows the operation through "-24 volt after time delay," which is the same for either 100- or 500-watt operation. Figure 9-12B continues the sequence for 100-watt operation; figure (fig. 9-12C) shows the sequence for 500-watt operation.

The main power input (top block of figure 9-12A is 117-volt, 60-cycle, single-phase power received from the ship's supply. Emergency switch MM controls the power input to the transmitter bay. When switch MM is closed, power is delivered to the cabinet heater switch, NN, and to the main power switch, RR.

When the start button of switch RR is depressed, the master control relay is energized, which distributes a-c power for the following purposes: to distribute a-c power throughout the transmitted bay, to energize all filament supplies in the transmitter bay, to energize the blower in the RFA, to energize the main power indicator, to turn on the +250-volt regulated and -12-volt power supplies in the LLRM, and, through the interlocks, to energize the LVPS time delay. After the time delay, the "-24-volt after time delay" supply is energized, which is a control voltage. With "-24 volt after time delay" the -220-volt and the +250-volt unregulated supplies in the LVPS are energized.

The following sequence applies with the service selector, U, on the LLRM set at the HAND position.

At this point for 100-watt operation (fig. 9-12B) with the standby operate switch, PP, in STANDBY, the carrier 100-watt ready indicator will be energized. If a different frequency is desired from the last previous transmission, the manual settings of the new frequency by adjustment of the control knobs on the RFO are made at this point in sequence followed by the corresponding manual band switching in the RFA, the readjustment of the initial setting of the two switches on the load adjusting unit (transmitter coupler), and then readjustment of the initial antenna tuning by the manual controls on the control indicator.

Placing the standby operate switch, PP in OPERATE energizes the +500-volt and +1050/+1300-volt supplies in the MVPS and energizes the 100-watt carrier on indicator. Energizing the +500-volt supply allows the +300-volt supply in the LVPS to energize. Placing the transmitter in a 'key down' condition will now energize the carrier, and manual tuning of the IPA and PA stages of the RFA is performed. The final fine antenna tuning adjustments are now made at the control indicator. Further adjustment of the switches on the load adjusting unit will be required only if satisfactory tuning is not accomplished with the switches in their initial setting.

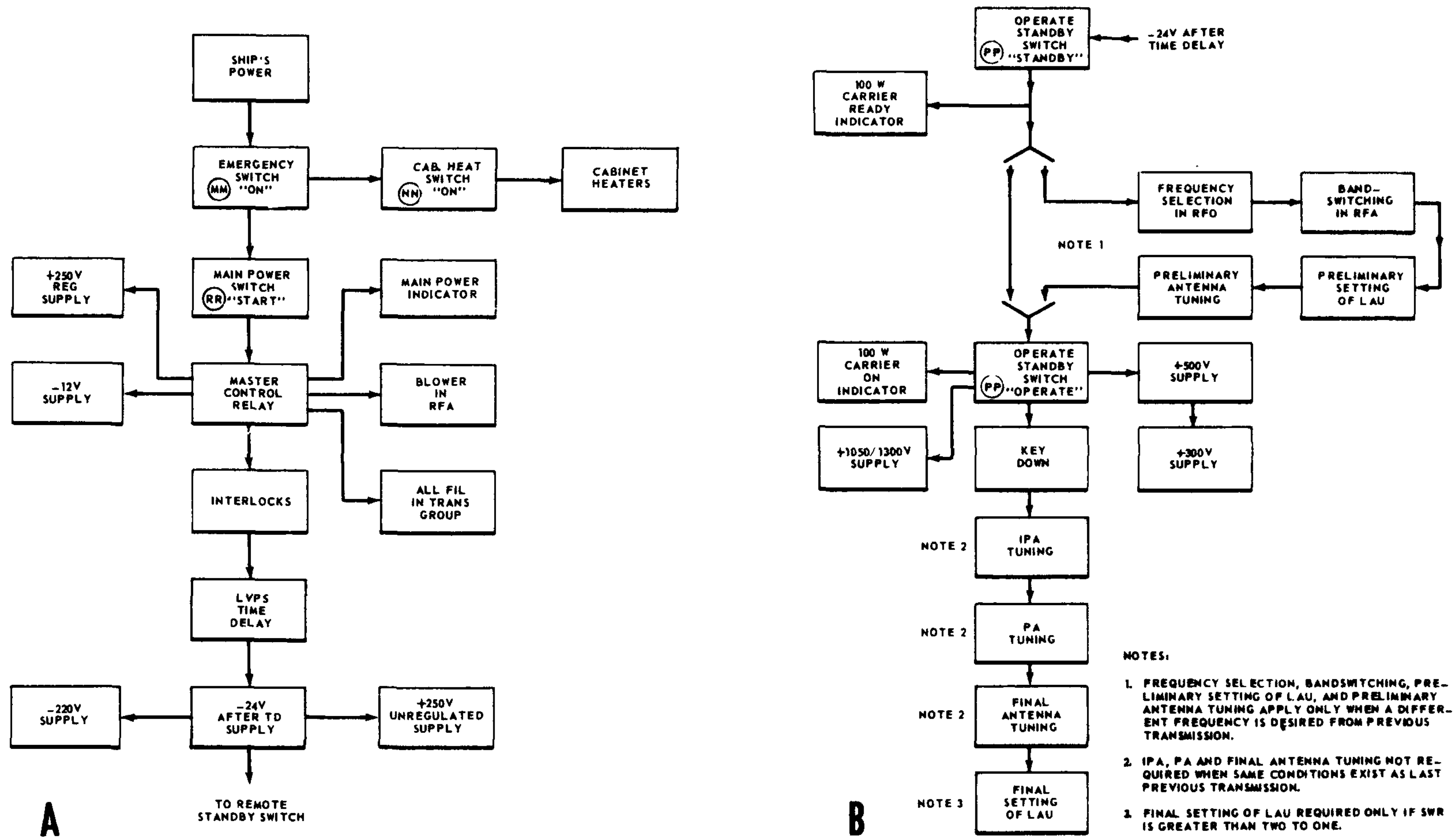


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Figure 9-12.—Functional block diagram of sequence of control circuit operation for AN/SRT-15 transmitter.

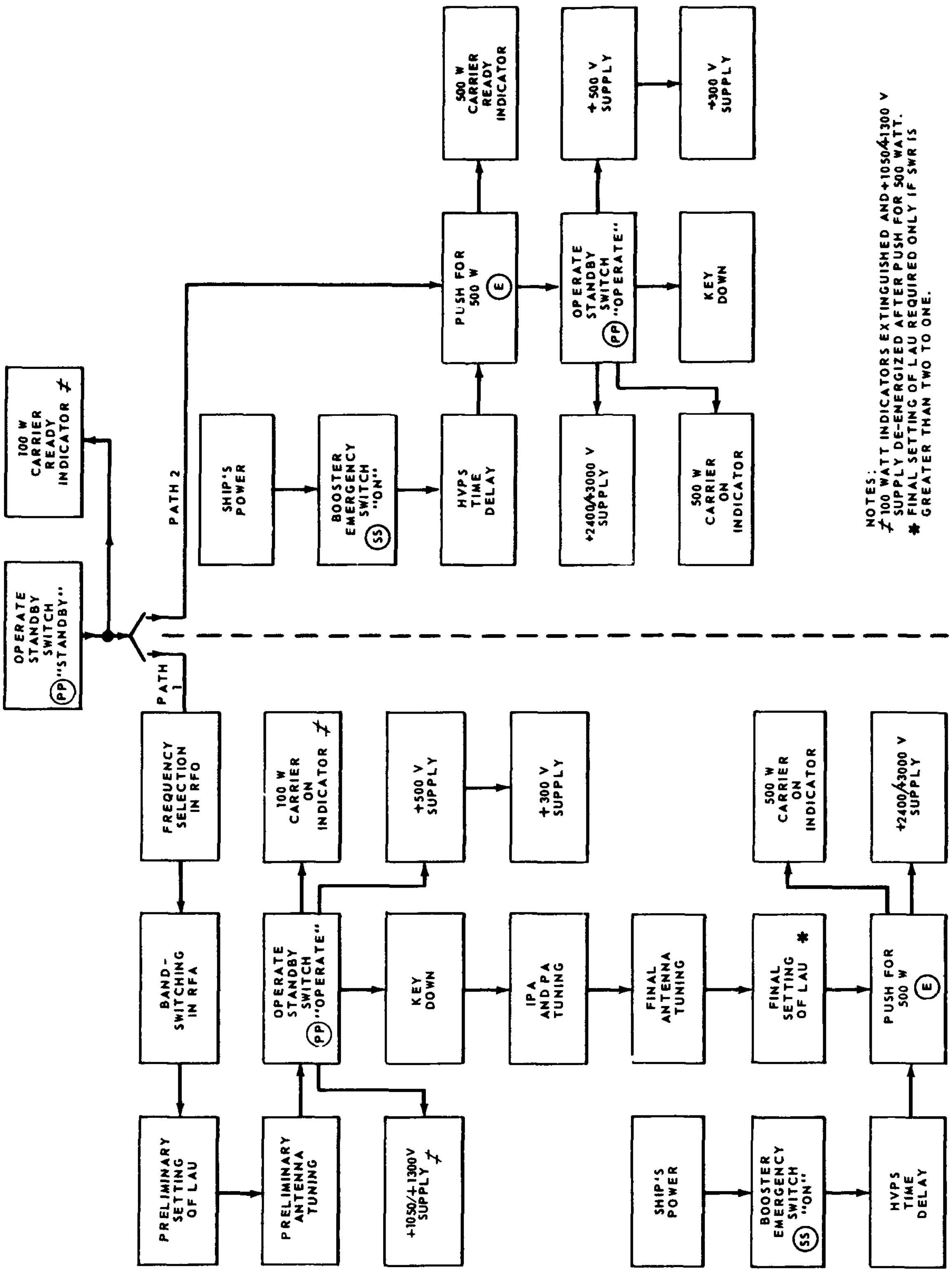

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Figure 9-12.—Functional block diagram of sequence of control circuit operation for AN/SRT-15 transmitter—Continued

For 500-watt operation (fig. 9-12C) after LVPS time delay, and with the standby operate switch, PP, in STANDBY, frequency selection, if required, takes place as previously described. The sequence now takes one of two paths, depending on whether or not tuning is required.

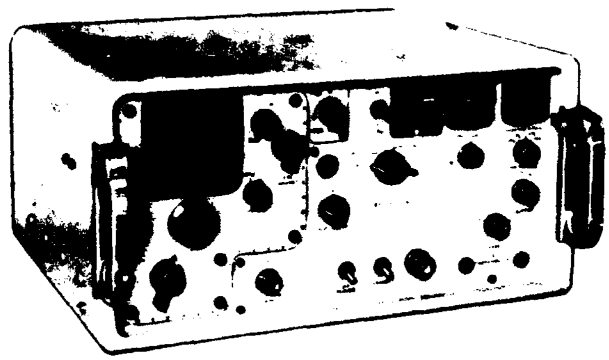
If tuning is required, it should be done with the transmitter energized at the 100-watt level (path 1), which gives the same sequence of operation as for 100 watts, as previously described. After tuning is complete, the booster emergency switch, SS, which controls power input to the booster, is turned on.

This action supplies either 220- or 440-volt, 60-cycle, three-phase power to the booster, energizing the HVPS time delay. After the time delay is over, the push for 500-watt button, E, is depressed, energizing the +2400/+3000-volt supply and the carrier 500 watt on indicator. Concurrently the 100-watt indicator and the +1050/+1300-volt supply are deenergized.

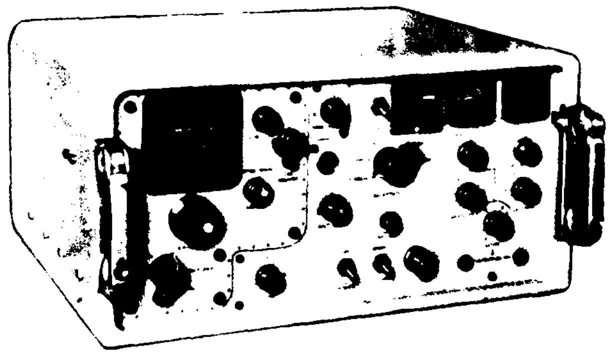
If no tuning is required (path 2), the booster emergency switch, SS, is placed in the ON position. When switch SS is closed, the booster receives either 220- or 440-volt, 60-cycle three-phase power from the ship's supply, energizing the HVPS time delay. After the time delay is over, the push for 500-watt button, E, is depressed, energizing the carrier 500-watt ready indicator. Placing the standby operate switch, PP, in OPERATE energizes the +2400/+3000-volt supply in the HVPS, the +500-volt supply in the MVPS, the carrier 500 watt on indicator (when the +500-volt supply is energized), and it allows the +300-volt supply also to energize. Placing the transmitter in a "key down" condition will now energize the carrier.

RADIO RECEIVING SETS AN/SRR-11, 12, 13

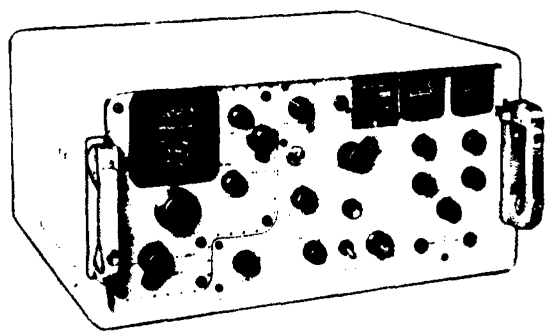
Radio Receiving Sets AN/SRR-11, 12, and 13 (fig. 9-13) are representative communications receivers designed for general application in all types of vessels of the U. S. Navy. The AN/SRR-13A receivers are illustrated in figure 9-13C. They are companion receivers to the previously described transmitting sets, AN/SRT 14, 15, and 16, and cover frequencies between 14 kc and 32 mc. A general description of these sets is given to acquaint the ET 3 with the nature of the circuits and components with which the external operating controls are associated. An explanation of the common



(A) AN/SRR-11



(B) AN/SRR-12 AND 13



(C) AN/SRR-13A

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Figure 9-13.—Radio receiving sets AN/SRR-11, 12, 13, and 13A.

operating adjustments on the AN/SRR-11 receiver is then given, and this is concluded with a summary of operating procedures.

GENERAL DESCRIPTION

The AN/SRR-11, 12, and 13 receivers are designed for table-top mountings. Each is

self-contained in a metal case with operating controls, switches, meters (tuning and output), phone jack connectors, and main tuning dial assembly mounted on the front panel. The receiver chassis is mounted on rails in the receiver cabinet and can be withdrawn and positioned 45 or 90 degrees (up or down) for ease in servicing.

The frequency range of each receiver is divided into five bands. Continuous tuning is available throughout each band. The frequency range of the AN/SRR-11 receiver is from 14 to 600 kc (low frequency), that of the AN/SRR-12 receiver is from 0.25 to 8 mc (medium frequency), and the range of the AN/SRR-13 receiver is from 2 to 32 mc (high frequency).

The AN/SRR-11 receiver is provided with circuits and switching to receive A1 (c-w telegraphy) signals, A2 (m-c-w telegraphy) signals, and F1 (telegraphy by frequency-shift keying) signals. In addition, the AN/SRR-12 and 13 receivers are capable of receiving A3 (radiophone) emissions.

A functional block diagram of the AN/SRR-11 receiver is illustrated in figure 9-14.

The basic receiver represented by the AN/SRR-11, 12 and 13 sets is a double superheterodyne having two stages of r-f amplification ahead of the first mixer and oscillator.

A first intermediate frequency amplifier (which is essentially the second converter) follows, and its output is fed to the second i-f assembly. Signals of A2 (m-c-w) and A3 (phone) emissions are rectified in a diode detector. The diode detector is bypassed when the receiver is switched to c-w or frequency-shift reception. Such signals are heterodyned in a beat frequency oscillator mixer stage with those from a BFO to produce a difference frequency in the audio range. A manual gain control or delayed automatic gain control circuit (depending upon the setting of the reception control) is provided to reduce the gain of the r-f and second i-f amplifiers when strong signals are received.

Audio frequencies are amplified through a four-stage amplifier, which feeds a balanced audio line and an unbalanced line for phone jack connections.

Circuits from the antenna stage through the first i-f amplifier are designed so that they will have different characteristics in order to provide for optimum reception on the several bands of frequencies covered by the low-, medium-, and high-frequency receivers.

In the AN/SRR-11 receiver the signal is fed from the antenna through the first and second r-f amplifiers, V101 and V126, to a mixer, V151, in which it is combined with the output of a local oscillator, V201. The output of the mixer has a frequency of 60 kc (bands 1 and 4) and passes through a band-pass filter, Z702, to a first i-f stage, V701, where it is converted to a frequency of 200 kc. This action is accomplished in a dual purpose tube, V701, which operates both as a crystal-controlled heterodyning oscillator (140 kc) and as a mixer. The 200-kc output is transformer coupled to the second i-f input assembly. This assembly includes filters Z1001 and Z1002; three stages of i-f amplification (V1001, V1002, and V1003) at 200 kc; a BFO mixer, V1004; diode detector, V1005; and a cathode follower, V1007 used to supply i-f signals to a frequency-shift converter or other accessory equipment.

The 200-kc input to the second i-f assembly is filtered before it is applied to the first amplifier, V1001. The filter selected depends on the position of wafer switches S1001 and S1002, which are actuated by the reception control. When this control is set at FSK, A1 broad, or A1 sharp, signals are fed through the "sharp" filter, Z1001, which provides a pass band of approximately 3.2 kc centered about 200 kc. When the reception control is set at A2 broad, the "medium" filter, Z1002, is used, which provides a pass band of approximately 8 kc centered about 200 kc.

On bands 2, 3, and 5 the first i-f input from the output of the mixer, V151, is 200 kc. On these bands the signal is bypassed around the first i-f filter, Z702, and the first i-f converter (oscillator mixer), V701. Plate and screen voltages are removed from X701, thereby rendering this stage inoperative.

The second i-f, power supply, beat frequency oscillator, and audio amplifier are similar for the AN/SRR-11, 12, and 13 equipments.

A crystal-controlled calibrator circuit is incorporated in each receiver to provide crystal check points. These check points are spread uniformly over the tuning range of the receivers and occur at 10-kc intervals for the AN/SRR-11, at 50-kc intervals for the AN/SRR-12, and at 200-kc intervals for the AN/SRR-13. The frequency check points are used in conjunction with the CAL adjust knob on the receiver front panel to calibrate the tuning dial.

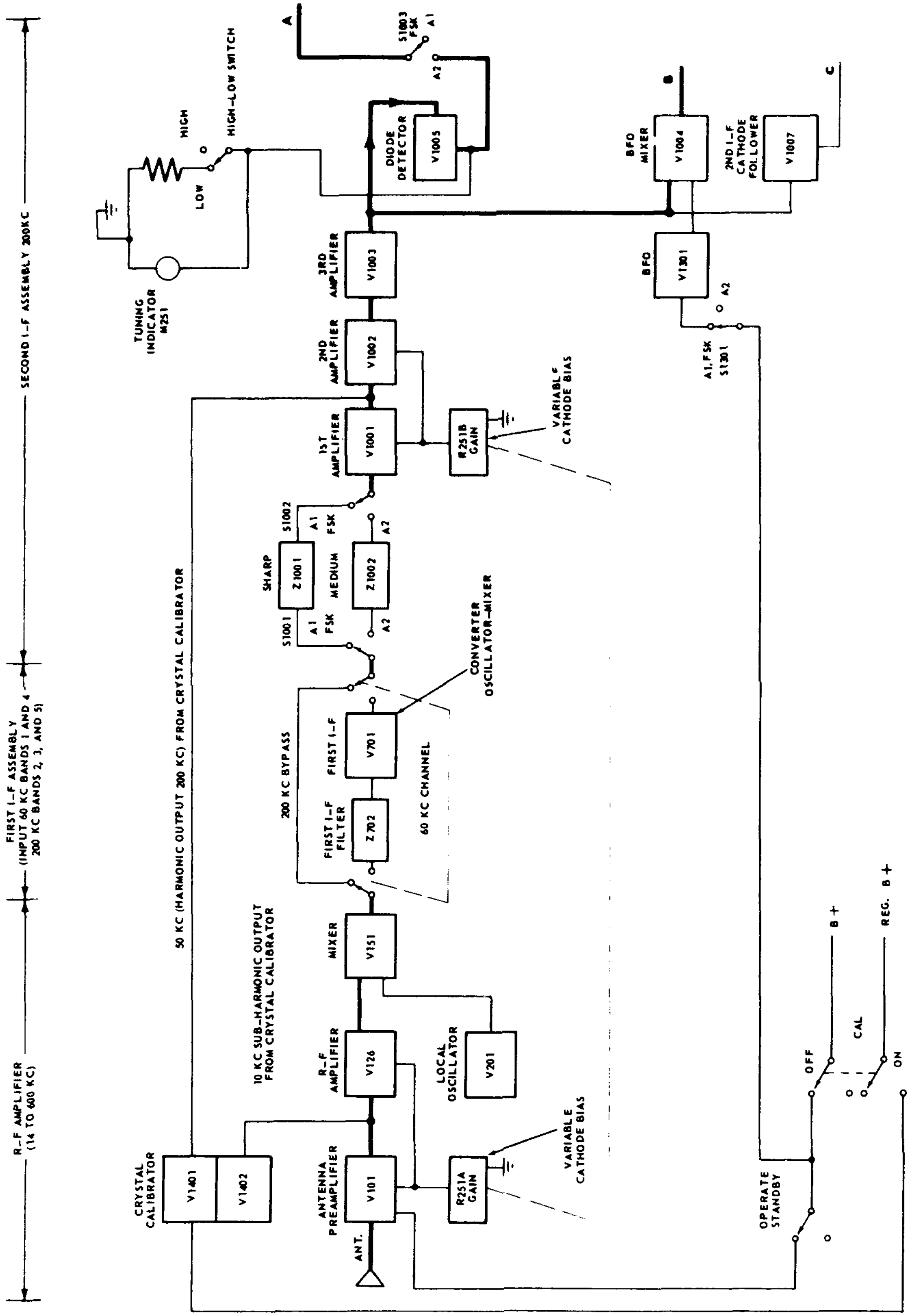

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Figure 9-14.—Block diagram of AN/SRR-11 receiver.

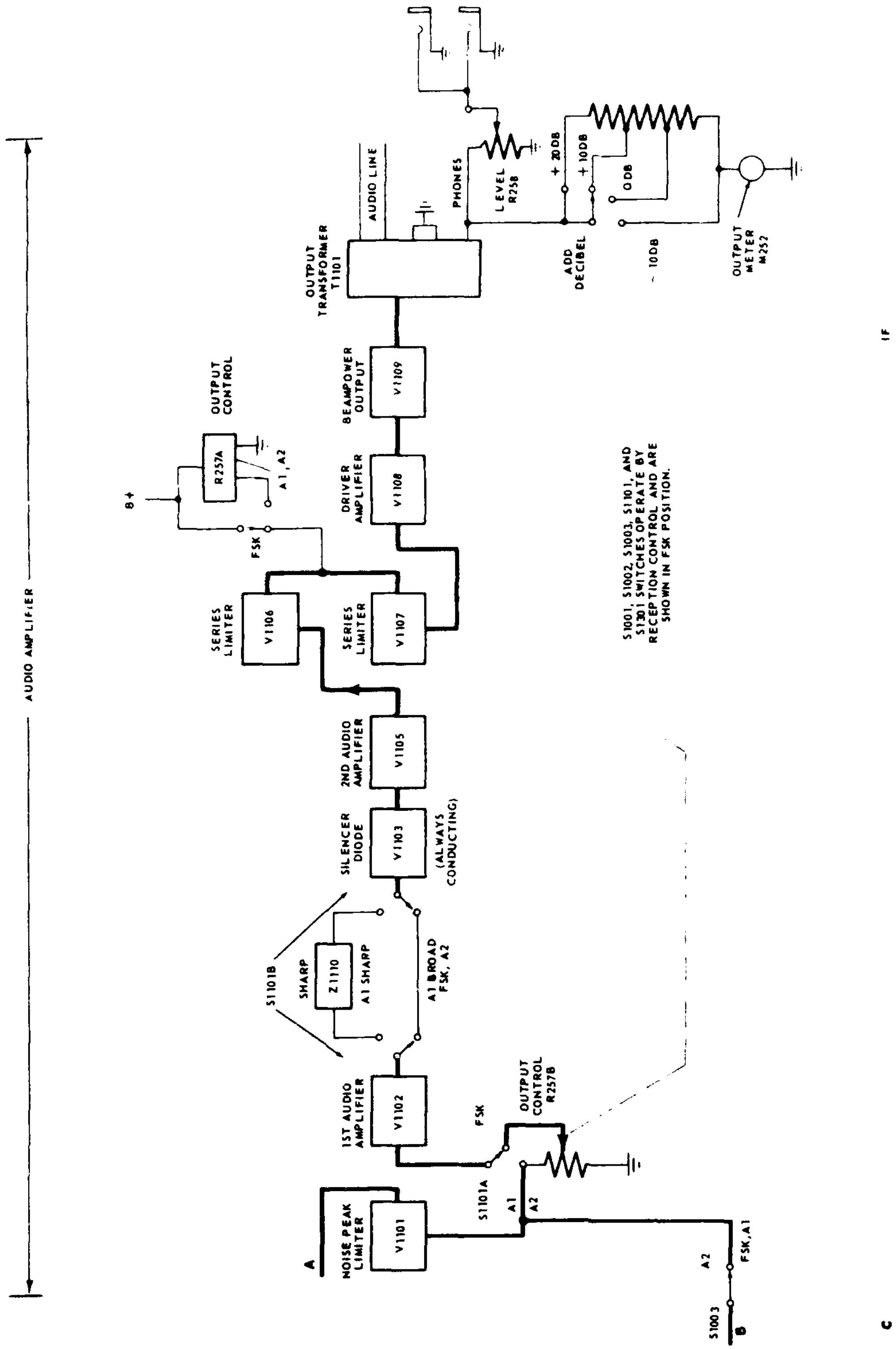

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Figure 9-14.—Block diagram of AN/SRR-11 receiver—Continued.

External connections are furnished from the AN/SRR-12 and 13 receivers to provide an AGC voltage and circuit connection to a common external diode load, so that these receivers may be operated with a companion receiver in a dual diversity reception system.

External connections are also furnished for feeding a frequency-shift converter of either the i-f or audio type. An additional external connection on the AN/SRR-12 and 13 is provided to supply i-f signals to a panoramic adapter.

The frequency to which the receiver is tuned appears projected on a translucent screen (tuning dial) located at the upper left of the front panel. The dial is calibrated in kilocycles on the AN/SRR-11 and in megacycles on the AN/SRR-12 and 13. The projection system consists of a glass disk on which the tuning range of the receiver is calibrated in five scales. A light source is mounted in a housing behind the tuning dial. A portion of one of the optical scales on the glass disk is projected through a system of lenses and onto a mirror that reflects the image of the scale back upon the translucent screen. The glass disk is rotated by gears as the tuning knob is turned. When the setting of the band switch is changed, the dial light and lens housing are moved up or down by a cam driven from the band switch gears to align the lens system with the corresponding frequency scale on the glass disk.

The CAL adjust knob and locking screw located to the right of the tuning dial provide a means of shifting the frequency scale on the translucent screen when recalibrating the receiver in conjunction with the crystal controlled calibrator. This action is accomplished by a slight horizontal movement of the lens system.

COMMON EXTERNAL ADJUSTMENTS

All operating controls and switches necessary for the operation of the three receiver types (AN/SRR-11, 12, and 13) are mounted on the front panel of the receivers together with two meters to be used when tuning and reading the output level. The functional name of each control and meter is marked on the panel near the particular control, as illustrated in figure 9-15. Figure 9-15A illustrates the front panel controls for the AN/SRR-11 receiver, and figure 9-15B illustrates the front panel controls for the AN/SRR-12, and 13 receivers.

Before operating the receivers, make sure that the chassis is firmly placed in the receiver cabinet. If the chassis is not firmly placed in the cabinet, no power will be applied to the receiver.

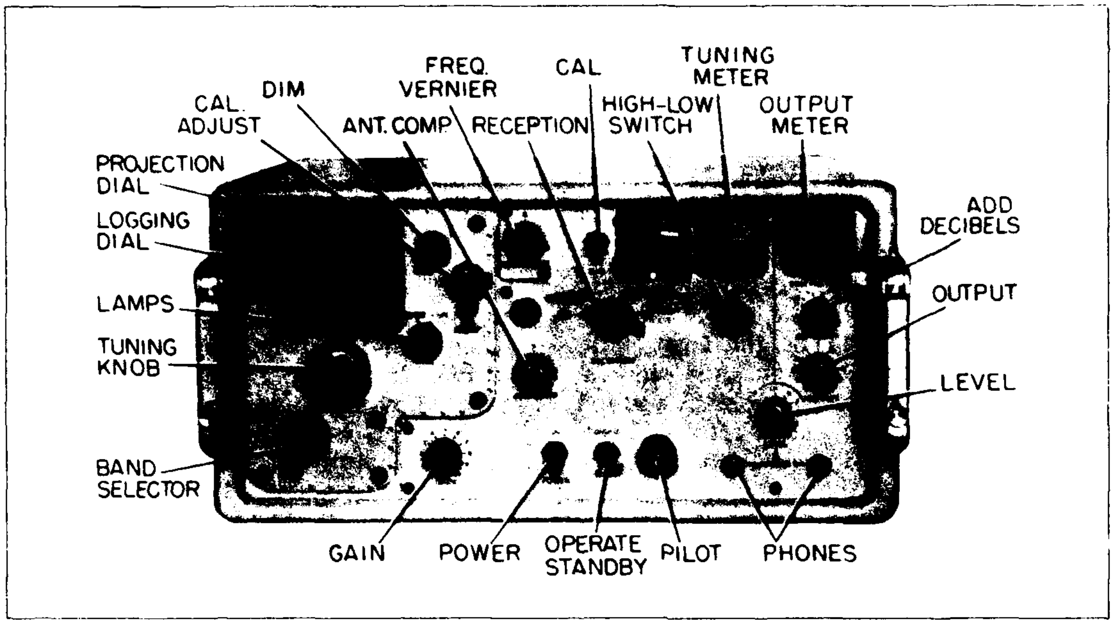
The on-off power switch applies primary power when in the ON position. When the operate standby switch (not included on the AN/SRR13A) is at STANDBY, plate voltage is removed from the antenna preamplifier. The pilot light is energized when high voltage is applied on the set.

The gain control, R251 A, and B (fig. 9-14) operates in the r-f and i-f stages. Maximum gain in these stages occurs when the control knob is turned fully clockwise. In this position the cathode bias, for example that of V101, V126, V1001, and V1002 in the AN/SRR-11 receiver is a minimum, and the $m\mu$ of these tubes is a maximum. The gain control is inactive when the reception control on the AN/SRR-12 and 13 is positioned at A3 sharp, A3 broad, or FSK.

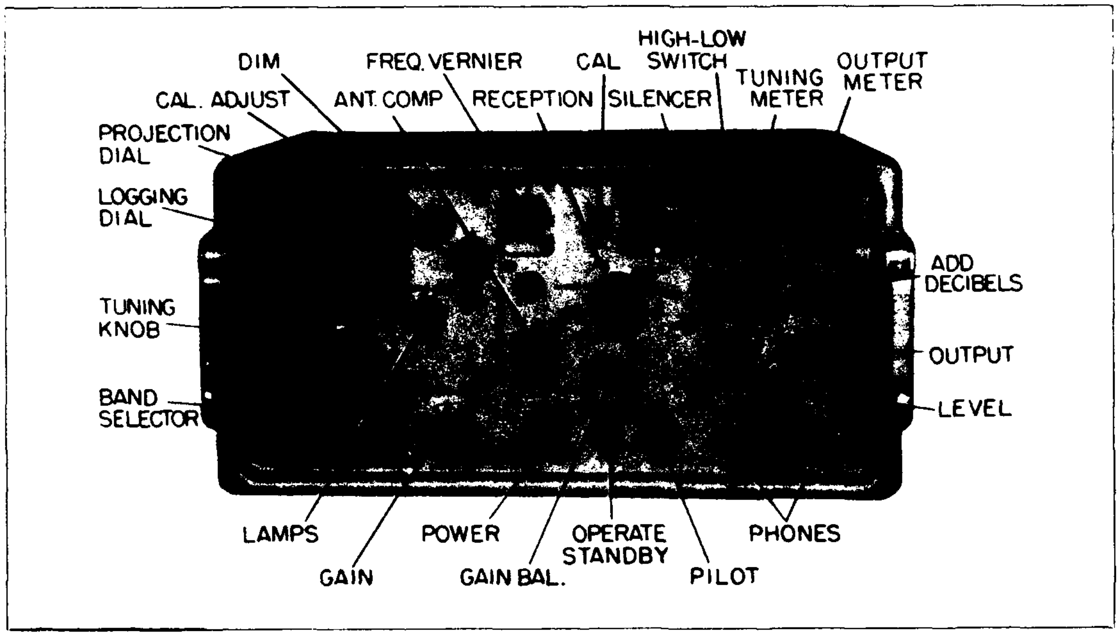
The Ant Comp (antenna compensating) control (not shown in the block diagram) provides a tuning adjustment for the antenna preamplifier to compensate for variations in the antenna impedance. This control actuates an air-dielectric trimmer capacitor (C103 figure 8-12 in Chapter 8) in shunt with the tuned circuit of the first r-f amplifier. A fixed mica capacitor (C102 figure 8-12) is also connected in series with the antenna input lead. This capacitor is shorted by a microswitch (S102 figure 8-12) operated by a cam on the shaft of the antenna compensating control for 180 degrees of rotation of the control, designated low. In this case, the primary circuit capacitance is that of the antenna. The switch is open for the second 180 degree rotation of the control, designated high, and the fixed capacitor is inserted in series with the antenna. In this case, the total capacitance of the antenna and fixed capacitor is reduced to match that of the primary input circuit.

The band selector provides selection of the tuning range of the receiver in any one of the five bands as discussed in chapter 8.

The tuning knob is used to tune the receiver to the desired frequency. The indication of this frequency appears on the translucent screen above the tuning knob, as previously described. A four-section, air-dielectric, ganged tuning capacitor is mechanically linked to the tuning knob. The four sections are connected across appropriate transformer coil groups in the grid circuits of the first and



A AN/SRR 11



B AN/SRR 12-13

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Figure 9-15.—Radio receiving sets AN/SRR-11, 12, 13—front panel controls.

second r-f amplifiers, the mixer, and the local oscillator. The linear scale below the translucent screen is a logging dial used to log stations. It is mechanically linked to the tuning knob control and is used as a convenient method of quickly locating a station.

The dim control knob is turned to vary the intensity of the dial light.

The lamp switch connects a spare dial light in the event of failure of the operating light.

The output control, potentiometer R257B (fig. 9-14) for the AN/SRR-11 receiver adjusts the signal level, for FSK signals, before the signal is applied to the grid of the first audio amplifier, V1102. For A1 and A2 signals, potentiometer R257A varies the voltage applied to limiter diodes V1106 and V1107. These diodes are combined to clip equally on positive and negative portions of the audio cycle when S1101A on the reception is set for A1 or A2.

The reception control on the AN/SRR-11 receiver is a four-position switch used to select the appropriate circuits for the type of signal being received. The FSK position provides circuits for receiving F1 (frequency-shift) signals when a suitable converter is connected to the receiver; a beat note is provided. The A1-broad setting is used for receiving c-w (unmodulated) signals; a beat note is also provided. The A1 sharp setting is used to separate c-w signals by narrowing the frequency response; a beat note is also provided. The A2 position provides for the reception of m-c-w signals; no beat note is provided. In addition to the four signal positions on the AN/SRR-11 reception control, the corresponding switches on the AN/SRR-12 and 13 receivers have two additional settings. These are designated A3 sharp and A3 broad. Both settings provide circuits for the reception of voice-modulated signals.

The silencer (AN/SRR-12 and 13 only) provides for the reduction of background noise when the reception control is set at A3 sharp or A3 broad, and the desired station is not transmitting. The silencer diode is in series with the signal circuit between the first and second audio amplifiers. When a strong carrier is present, this tube conducts and the signal is amplified. In the absence of a carrier the diode plate is negative with respect to the cathode, and the tube is cut off, thereby preventing noise from being further amplified by the succeeding a-f stages.

The frequency vernier varies the pitch of the beat note when the reception control is in the A1 broad, A1 sharp, and the FSK positions.

When CAL switch is in the ON position, frequency check points are provided.

The CAL adjust control is used to reset the projection dial after the desired check point frequency has been zeroed.

The tuning meter reads up scale (toward the right) when the desired signal is tuned to a maximum. The meter reads down scale (toward the left) when the desired station is detuned. The tuning meter is used in conjunction with the high-low switch.

The high-low switch normally is in the LOW position. In this position the tuning meter is protected by a resistor.

When the tuning meter reads on the lower part (left side) of the scale in the LOW position of the switch, use the HIGH position and tune the receiver slightly for an up-scale reading on the meter. The HIGH position of the switch is spring loaded; when released the switch will return to the LOW position.

The output meter reads the output power level between -20 db and +25 db when used in conjunction with the add decibel switch. Zero db is equivalent to 6 mw in a 600-ohm load.

The add decibel switch provides attenuation for the output meter circuit. The +10 decibel position should be used for checking strong output levels. The zero-decibel position is used to measure weak levels, and the -10 decibel position is used for a momentary reading of weak levels. The add decibel switch should be in the +20 decibel position when not using the output meter.

SUMMARY OF OPERATION

When starting the equipment, (1) make sure the receiver chassis is firmly in the cabinet, (2) turn the power switch to ON, (3) adjust the dial illumination by turning the dim control (turn the dim control fully counterclockwise to extinguish the dial light; should the dial light fail, switch the lamp knob to the SPARE position and replace the burned out light), (4) turn add decibel switch to the +20 position, (5) turn the standby switch to OPERATE (note that the pilot light glows except when the knurled ring around the light is turned clockwise), (6) make sure that the CAL switch is in the OFF position, and (7) plug one or two pairs of headsets into the jacks marked phones.

Two pairs of headsets can be operated from the receiver at the same time. Low-impedance phones (600 ohms nominal) similar to Navy type 49507 should be used. The level control regulates the gain through the headphones.

In order to tune a signal:

1. Turn the gain and output controls up (clockwise) until background noise is heard. Turn the silencer control fully counterclockwise. This control is effective only when the reception control is set at A3 sharp or A3 broad. (The silencer control is not included on the AN/SRR-11.)

2. Select the appropriate frequency band using the band selector control.

3. Calibrate the receiver at the nearest frequency check point.

To calibrate the receiver, turn the CAL switch on. Set the tuning dial at the nearest calibration marker (designated by an inverted V on the frequency scale). Rock the tuning knob slightly on both sides of the chosen frequency until a beat note is heard. Zero beat should occur at the calibration marker chosen. If zero beat does not occur at this marker, adjust the tuning knob until zero beat is indicated.

Then loosen the thumb screw holding the CAL adjust knob (turn counterclockwise) and turn CAL adjust knob until the nearest calibration marker is under the hairline on the projection screen. Tighten the thumb screw over the CAL adjust knob. Turn the CAL switch to OFF.

Tune in the desired station by setting the desired station's frequency under the hairline index on the projection screen by means of the tuning knob. Turn the antenna compensating control until the signal is the loudest. This control will have the most effect at the high end of each frequency band. Adjust the signal to maximum, as indicated on the tuning meter.

As the station is tuned in, the tuning meter reads up scale. When below 1/4 scale on the low setting of the high-low switch, hold the switch in the HIGH position and readjust the tuning knob for an up-scale indication of the tuning meter. (Never hold the high-low switch in the HIGH position when the tuning meter is at full scale with the high-low switch in the LOW position as this action would remove the protection afforded by the resistor.) Use of the tuning meter is optional for c-w signals (A1 broad or A1 sharp positions of the reception control).

To use the logging dial, the receiver should be calibrated, as previously described, and tuned to the desired station. The logging dial includes a fixed index and two movable scales immediately below the tuning projection dial. The logging dial is not affected by the CAL adjust knob. When the receiver is tuned to the desired station, record the settings of the two movable scales, using the index mark on the middle segment, as in the following example. The top scale reads between 200 and 300. The bottom scale reads 63. The setting of the logging dial is 263. By resetting this figure (263) on the logging dial for the same band-selector position, the previously received station can be returned quickly. The logging dial should always be set approaching from the same direction (clockwise rotation of the tuning knob).

Other tuning procedures will vary, depending on the position of the reception control and the class of emission of the desired signal.

When the receiver is supplying signals to a frequency-shift converter of the i-f type (similar to Navy Model CR-57/URR), tune the receiver to the desired station by means of the tuning knob and adjust the antenna compensating control for maximum signal, as indicated on the tuning meter.

When the receiver is supplying audio signals to a frequency-shift converter similar to Navy Model CV-60/URR, tune the receiver to the desired station by means of the tuning knob and then adjust the output and frequency vernier controls, as required for the operation of the frequency-shift converter.

RADIO TRANSMITTER-RECEIVER SET AN/GRC-27A

The Radio Transmitter-Receiver Set, AN/GRC-27A (fig. 9-16), is intended for shipboard installation, and is used for u-h-f communications from ship-to-ship, ship-to-shore, or with aircraft. The AN/GRC-27A comprises Radio Transmitter, T-217A/GR; Radio Receiver, R-278B/GR; Modulator-power Supply, MD-129A/GR; Distribution Panel, J-390/GR; and Control Radio Set, C-1897/GRC-27A.

The transmitter and modulator-power suppy together form a transmitting installation. The receiver is used separately for reception of either u-h-f voice modulated or mcw signals.

GENERAL DESCRIPTION

The transmitter normally generates a radio frequency carrier in a range from 225.0 to 399.9

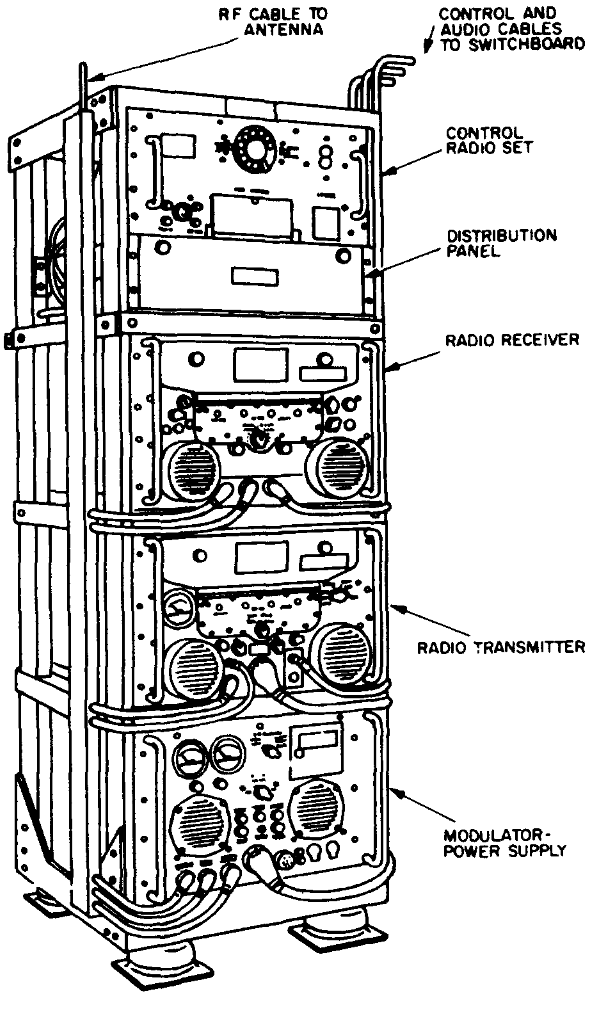

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Figure 9-16.—Radio transmitter-receiver set AN/GRC-27A.

mc with a nominal power output of 100 watts over this range. The transmitter employs 3 crystal-controlled oscillators (frequency generators) which employ a total of 38 crystals. The combination and multiplication (synthesizing) of these 38 crystal frequencies make it possible to produce 1750 frequencies spaced at 100-kc intervals from 225.0 to 399.9 mc. Any 10 of these 1750 frequencies can be manually preset by a series of selector switch dials (calibrated in megacycles) in 100-kc increments. Any *one* of these 10 frequencies (channels) can be selected automatically, either locally or from a remote station. Automatic selection of a preset channel is accomplished in 2 to 7 seconds by a combined autopositioner drive system and a *servosystem*.

The modulator-power supply provides the transmitter with all necessary operating and control voltages, and supplies amplitude modulation power (either voice or mcw tone) for the transmitter. The transmitter output includes both upper and lower sidebands generated when the carrier is amplitude modulated.

The receiver normally operates on any one of 1750 frequencies spaced at 100-kc intervals from 225.0 to 399.9 mc. The receiver employs a triple conversion superheterodyne system using crystal-controlled oscillators, and employing a total of 38 crystals in a synthesizer system. Any 10 channels of the 1750 frequencies can be manually preset, and then, any one of the 10 can be automatically selected either locally or from a remote station.

Automatic channel selection in the receiver is accomplished by a frequency selector and autopositioner system similar to that in the transmitter. A motor-driven system of gear trains operates the various crystal switches and tuning mechanisms to permit rapid change of operating frequency. Here again, automatic *shifting* of channels can be accomplished in 2 to 7 seconds.

The receiver is designed for use with directional or omnidirectional antennas having a characteristic impedance of 52 ohms. Audio output circuits for operation of loudspeakers and for operation into telephone lines are built into the receiver. A special output circuit for direction-finding applications is also provided. The receiver is equipped with automatic volume control, automatic noise limiter, and carrier-operated squelch circuits.

The preset channels for the transmitter or the receiver are selected by operating a channel selector switch on the front panel of the respective units or by telephone-type dials on associated radio set control facilities.

The radio set control C-1897/GRC-27A, adapts the control circuits of the Radio Set AN/GRC-27A to the standard 12-wire shipboard remote system. The control provides for the control of power for Radio Set AN/GRC-27A, starting and stopping the modulator-power supply, automatic channel selection in the transmitter and receiver, local or remote control of the transmitter, and squelch adjustment for the receiver.

RADIO RECEIVER R-278B/GR

The receiver R278B/GR, figure 9-17 consists of four major sections: (1) a multi-channel receiver section, (2) a frequency selector system, (3) an audio amplifier section, and (4) a power supply.

Multi-channel Receiver Section

The multi-channel receiver section normally operates on any one of 1750 frequencies ranging from 225.0 to 399.9 mc as stated previously. The system includes RF, IF, mixer, detector, and noise limiter stages, to be discussed later.

Frequency Selector System

The frequency selector system mechanically tunes the receiver to any one of 1750 available frequencies. Essentially, the system consists of two main parts; the preset panel and the autopositioners (fig. 9-18). The preset panel provides switches for presetting 10 automatically tunable channels, and for setting up one manual channel. The autopositioner is an electromechanical device actuated by operating a channel selector switch located on the front panel of the receiver, or by remote control facilities. The autopositioner tunes the receiver to a desired channel selected from the 10 preset channels. The manual channel can be selected only from a panel-mounted channel selector switch, not shown.

PRESET PANEL.—The preset panel (fig. 9-18) employs 33 rotary switches. For purposes of setting up channels, these switches are arranged in 11 horizontal banks of 3 switches each. The "tens" mc frequencies are set up on the first bank, the "units" are set up on the second bank, and the "tenths" on the third bank.

For example, if a frequency of 245.6 mc is to be selected, the "tens" mc switch should be set to 24, the "units" switch to 5, and the "tenths" switch to 0.6. By combining the setting of the 3 switches (horizontal rows), the frequency of each of the 11 channels can be read directly on the front panel of the receiver.

The manual channel is set up the same as the other 10 channels, except that it is not possible to select the manual channel from a remote position. This channel is reserved for the local operator.

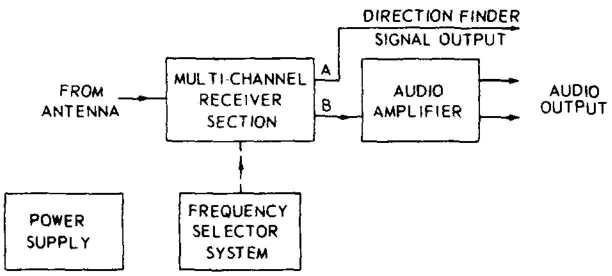

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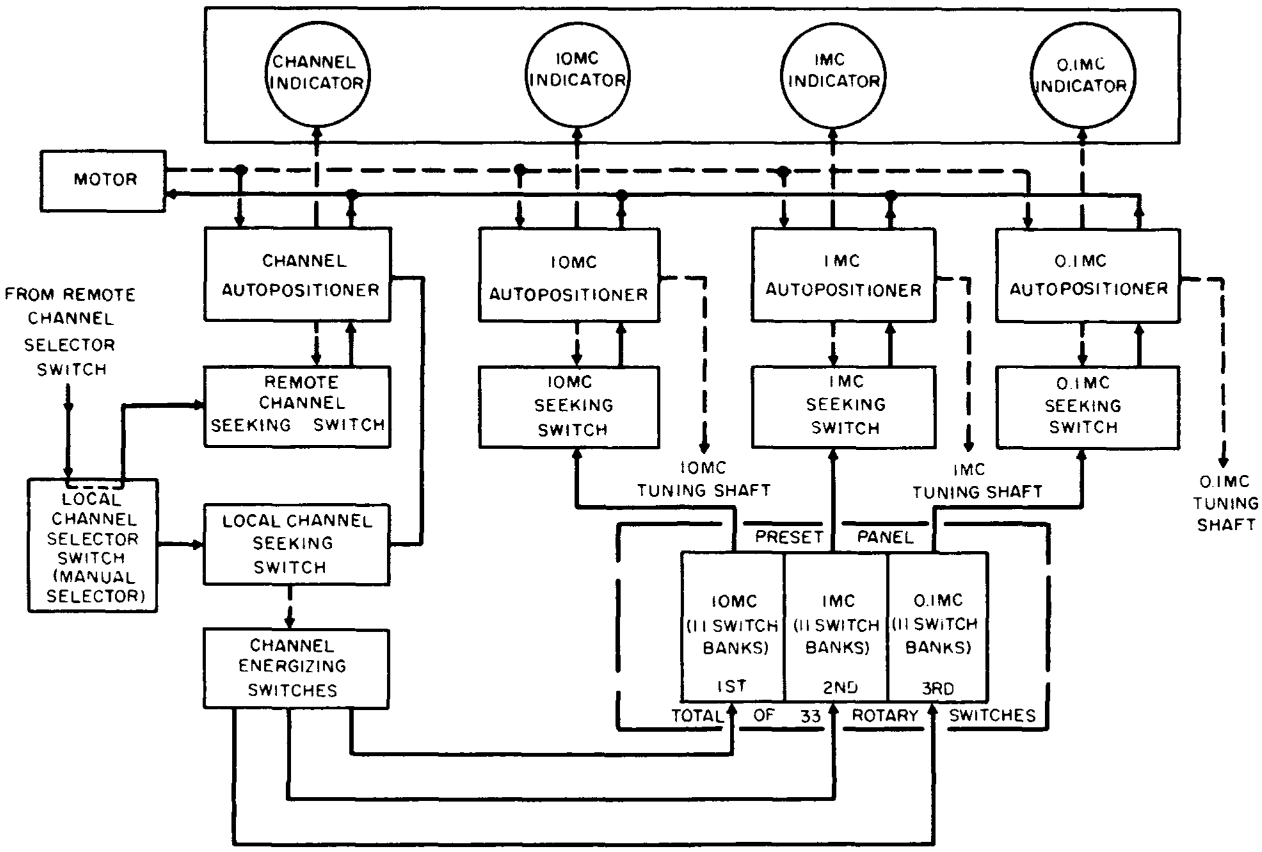
Figure 9-17.—Radio receiver R-278B/GR-major sections.

AUTOPOSITIONERS.—Associated with each autopositioner is an electrical control system consisting of a control switch and a corresponding symmetrical "seeking" switch which is driven by the autopositioner shaft (fig. 9-19). This control system is designed so that when the control switch and seeking switch are not set to the same electrical position, the autopositioner is energized and operates to drive its shaft (and the driven elements to which it is coupled) to the proper position to restore the symmetry of the control system.

When the control and seeking switches are in corresponding positions, the ground is removed from the motor control relay, the pawl is engaged in a notch on the stop wheel, and the motor is not energized. In this position, the autopositioner is at rest.

If the operator changes the position of the remote control switch, the symmetry between the remote control and seeking switches will be upset. In this condition, a ground connection is established through the seeking switch to the motor control relay, causing this relay to become energized. The current through the solenoid of the motor control relay exerts a magnetic attraction on the pawl which lifts the pawl out of the notch on the stop wheel. The grounded motor control relay contact arm is mechanically operated by the pawl, so that as the pawl is removed from the notch a ground is simultaneously applied to the solenoid of the motor start relay. The operation of the motor start relay closes another set of contacts which apply power to the motor.

As the motor turns, it drives the autopositioner shaft and the rotor of the seeking



32.112

Figure 9-18.—Frequency selector system, block diagram.

switch. When the seeking switch reaches the point corresponding to the new position of the remote switch, the ground is again removed from the motor control relay. The pawl drops back into a notch on the stop wheel to stop the shaft rotation. Simultaneously, the ground is removed from the motor start relay. The contacts which were applying the 115-volt a-c power to the motor are now released, and the motor stops.

Audio Amplifier Section

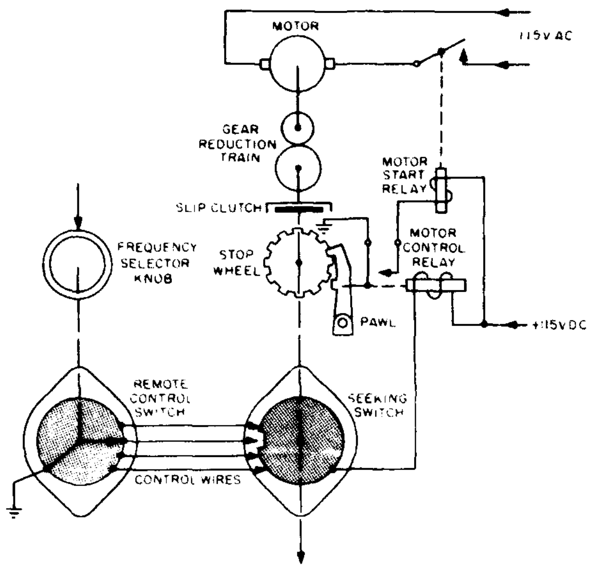
The audio amplifier section increases the amplitude of the audio before it is applied to the loudspeaker or telephone line output circuits. Two output circuits are provided; the main audio output, and the low level audio output.

Power Supply

The power supply consists of filament, bias, relay, and plate supply transformers, power supply rectifiers, and a filter system. Three gas rectifiers in conjunction with the transformers and filter provide the voltages necessary for operation of the receiver.

Operation

The frequency selector unit (fig. 9-20) has three output shafts which, by mechanical drive, select the proper crystals and tune various circuits to establish a particular operating frequency. These output shafts are called the 10-mc, the 1-mc, and the 0.1-mc shafts, respectively. The 10-mc shaft rotates in 18 incremental steps, each increment representing



32.113
Figure 9-19.—Autopositioner, basic elements.

10 mc. The 1-mc shaft rotates in 10 incremental steps, each step representing 1 mc. The 0.1-mc shaft rotates in 10 incremental steps, each step representing 0.1 mc.

The r-f amplifiers, V101 and V102, may be tuned in 18 incremental steps by the 10-mc shaft and in 10 incremental steps by the 1-mc shaft. For each position of the 10-mc switching shaft, the 1-mc shaft can be rotated through 10 positions, thereby tuning the r-f amplifiers to 10 different frequencies for each position of the 10-mc shaft. In this manner, the r-f amplifiers can be tuned to 180 frequencies in steps of 1 mc.

The antenna input signal is amplified in the first and second r-f amplifiers, V101 and V102, and fed to the first mixer, V401. The r-f signal input to the first mixer is heterodyned with the input signal from the first injection system to produce the first intermediate frequency between 40.0 and 49.9 mc.

The first injection system (comprising the main oscillator and frequency multiplier-amplifier stages) is tuned in eighteen 10-mc steps by the 10-mc output shaft. This shaft also operates the main oscillator crystal selector switch to select one of 18 crystal units (not shown). The first injection system output is fed from amplifier V305 to the first mixer stage, V401. The signal from the first mixer (between 40.0 and 49.9 mc) is amplified in the first i-f amplifier, V402.

The first i-f amplifier, V402, employs two permeability tuned transformers, one at the input to the stage and the other at the output. The powdered iron cores of these transformers are driven by the 1-mc and 0.1-mc shaft. The rotation of these shafts is combined in a differential tuning mechanism to produce one hundred 0.1-mc steps. The first i-f amplifier output is applied to the second mixer, V403.

The crystal selector switch and tuned circuits of the second injection oscillator, V404, are controlled by the 1-mc shaft. The 31- to 40-mc signal from the second injection oscillator, V404, is heterodvned in the second mixer, V403, with the 40.0- to 49.9-mc injection signal from V402. The difference frequency (9.0 to 9.9 mc) is fed to the second amplifier, V501.

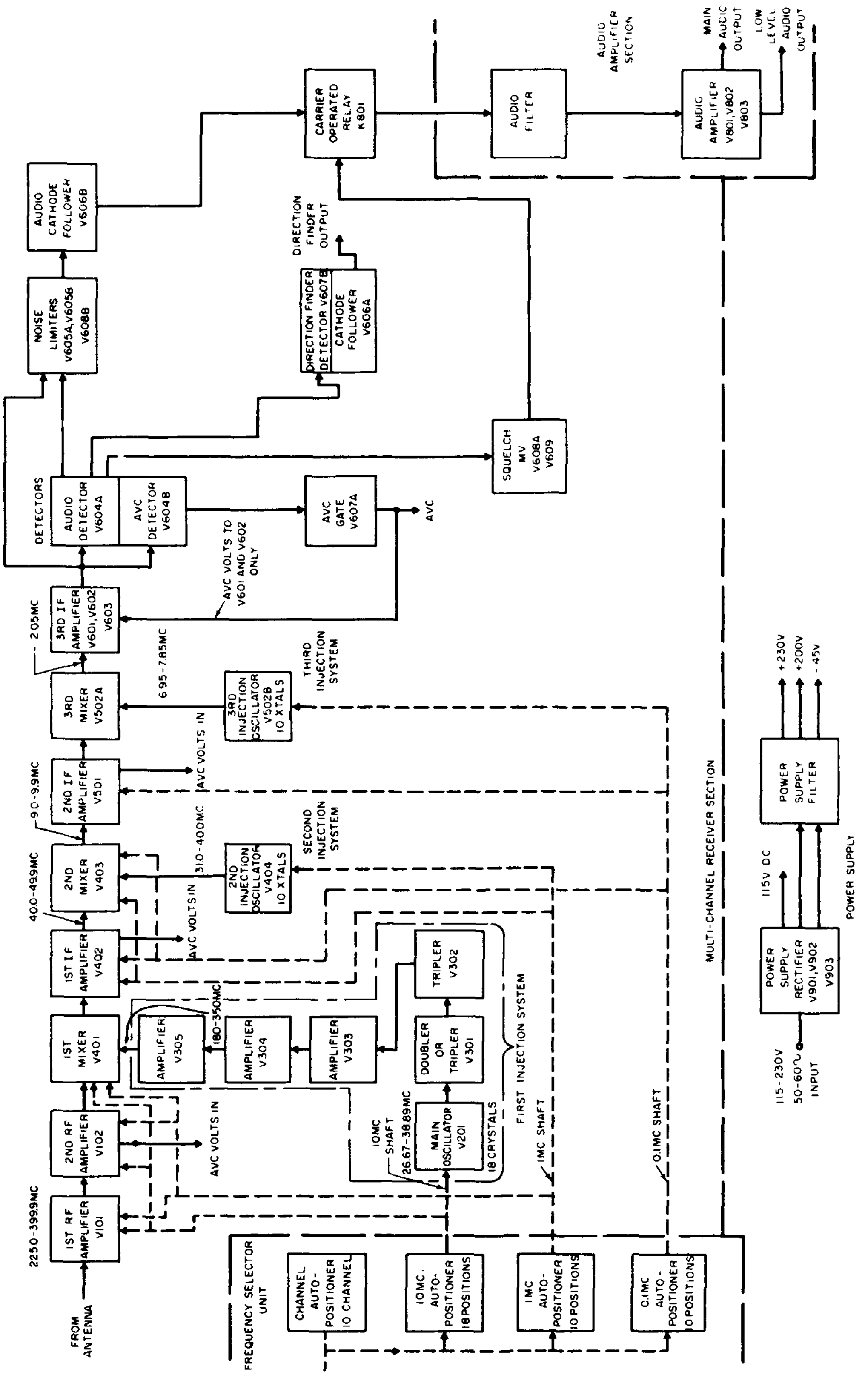
The second i-f amplifier, V501, is tuned in ten 0.1-mc steps by the 0.1-mc shaft. The 9.0- to 9.9-mc output from the second i-f amplifier is fed to the third mixer, V502A.

The third injection oscillator, V502B, is also tuned in 0.1-mc steps by the 0.1-mc shaft. The heterodyning frequency from the third injection oscillator, V502B, is between 6.95 and 7.85 mc. The final heterodyning process in the third mixer produces a 2.05-mc intermediate frequency. The third mixer output is amplified in three stages of i-f amplification, comprising V601, V602, and V603.

Two detector stages are employed in the receiver. The audio detector, V604A, is used to rectify and filter the audio component of the received signal. The AVC detector, V604B, is used to produce a d-c (AVC) control voltage for various amplifying tubes. The audio signal from V604A is routed through the noise limiter stages, V605A, V605B, and V608B. These stages reduce any spurious noise appearing in the received signal.

The AVC detector, V604B, and the AVC gate, V607A, produce the AVC control signal which is applied to the r-f and i-f stages of the receiver to maintain the audio output level nearly constant for wide variations in the amplitude of the r-f input signal.

The squelch circuit, V608A and V609, produces a d-c voltage to operate the carrier operated relay, K801. The relay functions to increase the audio signal amplitude to the filter



32.111

Figure 9-20.—Block diagram of radio receiver R-278B/GR.

(attenuator quieting control) in the audio path whenever a signal is received.

The direction-finder stages of the receiver, V607B and V606A, make possible the use of the receiver with a direction-finder system such as the Radio Direction Finder AN/CRD-6. This feature of the receiver is not required in the normal communications applications of the Radio Set AN/GRC-27A, aboard ship.

When the carried operated relay is energized, the audio signal from the audio filter is amplified in three stages, V801 and V802, and V803. Twin triode, V801, comprises two cascade connected single-ended audio amplifiers, and V802 and V803 are connected in a push-pull amplifier arrangement.

Two output circuits are provided, which are referred to as the main audio and the low-level audio outputs, respectively. The main audio output at the phone jack delivers approximately 3 watts into a 600-ohm balanced load. The low-level audio output is approximately 10 milliwatts, for operation of external equipment.

RADIO TRANSMITTER T-217A/GR

Radio Transmitter T-217A/GR, and its associated Modulator-Power Supply MD-129A/GR, constitute the radio transmitting installation of Radio Set AN/GRC-27A. The transmitter normally delivers a nominal output power of 100 watts, either tone or voice modulated, in the frequency range of 225.0 to 399.9 mc. Like the receiver, the transmitter has a maximum frequency range of 20 to 399.9 mc.

A block diagram of the major sections of the transmitter is shown in figure 9-21. It can be seen that the transmitter is essentially a frequency generating system, an exciter and driver, and a power amplifier. The modulator-power supply provides the transmitter with power, and voice or tone which modulates the output stage of the transmitter.

The transmitter employs a frequency selector system that automatically tunes the multichannel transmitter to any one of 1750 crystal-controlled frequencies in the range from 225.0 to 399.9 mc. This system is identical to the system used in the radio receiver.

Modulator-Power Supply

The modulator-power supply has two main functions. It provides all necessary power to Transmitter T-217A/GR, and the modulator audio output modulates the transmitter r-f carrier.

The power supplies of the modulator-power supply (fig. 9-22) are conventional a-c rectifier circuits supplied by three transformers. The filament transformer, T1405, is energized as soon as the main switch is closed. The low voltage transformer, T1407, is energized through time delay relay, K1403, and case interlock switch, S1410. The high voltage transformer, T1406, is energized through the bush to talk relay, K1404, and bias interlock relay, K1405.

Operation

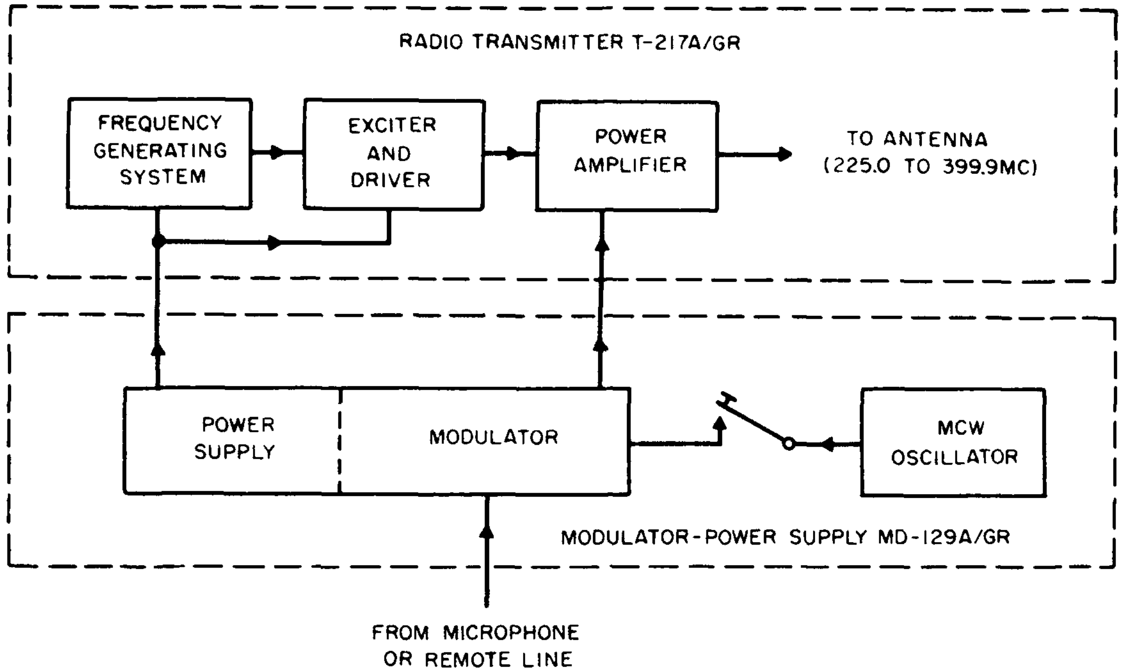
The main oscillator, V201 (fig. 9-23), generates the basic frequency for the transmitter. The oscillator employs 18 crystals which are selected by the 10-mc autopositioner to tune the oscillator from 31.111 to 45 mc. This cirucit is also referred to as the 10-mc frequency generator since the output frequency of V201 is changed one time for each 10-mc change in the transmitter output frequency.

The 31.111- to 45.0-mc output of the main oscillator is doubled or tripled in frequency multiplier, V301. Pentode, V301, operates as a doubler circuit when the output frequency of the transmitter is 299.9 mc or below. For frequencies above 299.9 mc, V301 operates as a tripler circuit. The chosen output of V301 is tripled in a second frequency multipler, V303. Amplifiers V302, V304, and V305 are also a part of the frequency multiplier-amplifier.

The frequency multipler-amplifier produces one of 18 frequencies spaced at 10-mc intervals. The frequencies are 200 to 370 mc and are delivered to the mixer, V406. The heterodyning frequency for the mixing section in V406 is obtained in the following manner:

The 1-mc frequency generator, V404, contains 10 crystals which are selected by the 1-mc autopositioner. This stage generates any one of 10 frequencies at 1-mc intervals in the 18- to 27-mc frequency range. The frequency generated is determined by the crystal selected and also by the tuning of the V404 output circuit by the 1-mc autopositioner.

A second frequency generator referred to as the 0.1-mc frequency generator, V402, contains 10 crystals which are selected at 0.1-mc intervals. The frequency range is from 2.0 to 2.9 mc, as determined by the selected crystal.



32.123

Figure 9-21.—Radio transmitter T-217A/GR-major sections.

The output frequencies of the two frequency generators (V404 and V402) are heterodyned in mixer, V401, to produce the sum frequency (20.0 to 29.9 mc). This sum frequency output is amplified in V403 and V405, and fed to mixer, V406.

The incoming frequency from the frequency multiplier-amplifier (200 to 370 mc) and the output from V405 (20.0 to 29.9 mc) are heterodyned in V406 to yield the sum frequency (220.0 to 399.9 mc). Because of the tuning differential between the 1-mc and 0.1-mc frequency generators, the output from the mixer, V401, can be any of 100 frequencies.

The signal from the mixer, V406, is amplified in the exciter, which comprises V101 and V102. The exciter output signal from V102 is amplified in three stages, V501, V502, and V503. The exciter and driver stages are tuned by the 10-mc and 1-mc autopositioners in 1-mc steps from 220.0 to 399.9. The amplifier stages in the exciter and driver are tuned to the center frequency of each 1-mc band. The bandpass of these stages is broad enough to amplify the 0.1-mc variations.

V601 and V602 amplify the driver (V503) output signal to produce a nominal output power of 150 watts. A servosystem, employing servomotor, B601, is used to tune the power amplifier throughout the frequency range of the transmitter. The servoamplifier circuit receives its error signal input from a servo bridge.

A basic representation of the tuning bridge includes potentiometers R and R'. Both resistors are connected across the 115-volt a-c line input. Actually, this load across the bridge consists of the input circuit to the grid of the first amplifier, V701 (not shown). Since the input circuit to V701 is grounded, the load across the bridge is connected between the arms of R and R'. Note that the arm of R is positioned by the 10-mc and 1-mc autopositioner shafts, and that the arm of R' is positioned by a mechanical connection to the servomotor.

If the power amplifier is on frequency, the potential at the arm of R will be the same as on the arm of R' and the voltage difference across the load (V701 input) will be zero. The bridge is therefore balanced, the motor

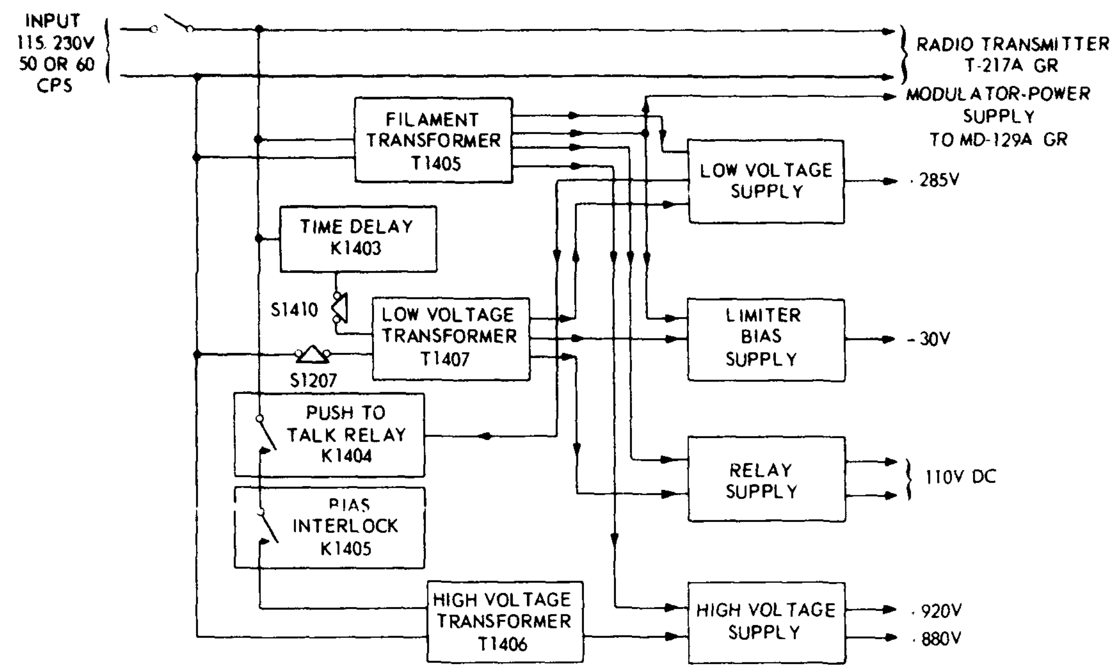


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Figure 9-22.—Modulator-power supply MD-129A/GR power supply block diagram.

is not turning, and the error signal is zero. However, if the balance of the bridge is upset, as will be the case when a new channel is selected, the 10-mc and 1-mc autopositioners move the arm of R in an attempt to select the new frequency. Thus, the bridge becomes unbalanced when the potential at the arm of R differs from that at R'. This potential difference represents the error signal which is applied to the input of V701.

The output of V701 is amplified in V702, V703, and V704. The amplified output drives the servomotor, B601, which mechanically tunes the power amplifier. Simultaneously, the servomotor drives the arm of R' until its position corresponds with the new position of R.

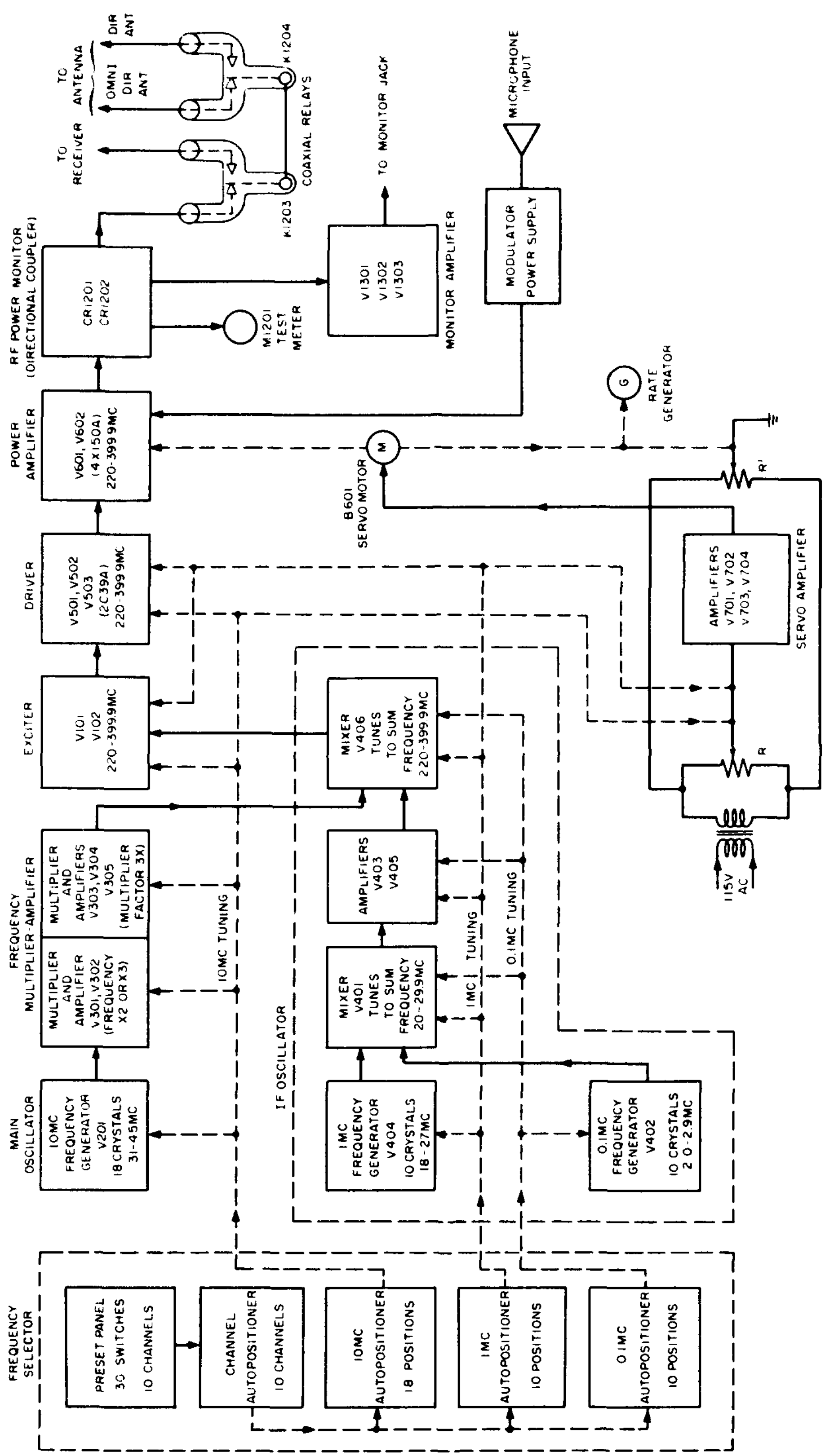
The direction of the error signal is determined by the direction of movement of R from its zero error position. The direction of rotation of the servomotor also is determined by the direction of the error signal.

The output of the power amplifier is fed through coaxial filters (not shown in the block diagram) which employ five tuned stubs to discriminate against frequencies above 450 mc. The output of this filter is connected to the r-f power monitor.

Two directional couplers are used in the r-f power monitor to provide two sampling voltages. The output from one directional coupler is used to indicate power output, to supply an input to the monitor amplifier, and to calibrate a standing wave ratio indicator. The output from the other directional coupler provides standing wave ratio indication in conjunction with test meter, M1201, by measuring reflected power.

The signal from the r-f power monitor is passed to the antenna transfer relay, K1203. This relay works in conjunction with the push-to-talk circuit, transferring the antenna from the receiver to the transmitter when the push-to-talk circuit is energized. The circuitry is arranged so that the antenna is transferred before the high voltage is applied to the transmitter.

A directional or omnidirectional antenna may be selected by the antenna selector switch (S1209) and used with the transmitter. The transmitter output is fed



32.124

Figure 9-23.—Radio transmitter T-217A/GR, functional block diagram.

from K1203 through K1204 to the selected antenna.

OPERATING PROCEDURE

All controls required for normal operation of Radio Transmitter-Receiver Set AN/GRC-27A are mounted on the front panels (fig. 9-24). A brief summary of the procedure in setting up the set for operation follows:

1. Turn the EMERGENCY switch on the radio set control panel (fig. 9-24A) and the POWER switch on the modulator-power supply (fig. 9-24B) to ON.
2. Press the START switch on the radio set control panel. The POWER ON indicator on the modulator-power supply panel, and the FIL (filament) indicator on the transmitter panel (fig. 9-24C) should now be lighted. After about 30 seconds the STANDBY indicator on the modulator-power supply panel should light indicating that the transmitter is in standby condition.
3. Turn the POWER switch on the receiver panel (fig. 9-24D) to on. The POWER INDICATOR should light indicating the receiver is in standby condition.
4. Set each of the 11 channels to the desired frequency with the knurled disc switches provided on the transmitter preset panel (inside door fig. 9-24C). Any one of the channels may now be selected by the transmitter CHANNEL SELECTOR switch, or channel selection for channels 1 through 10 may be transferred to a remote position by turning the CHANNEL SELECTOR switch to the remote position.
5. Set the receiver channels to the desired frequencies as described for the transmitter.
6. Turn the transmitter TEST METER SELECTOR switch to the power output-watts position, and the ANTENNA SELECTOR switch to OMI. ANT
7. On the modulator-power supply panel, turn the METER SELECTOR switch to % mod., the NORMAL-EMERG. switch to EMERG. the MCW-CARRIER ON-VOICE switch to voice, and the AUDIO BANDWIDTH switch to normal. For normal operation the LIMITER CONTROL is set between positions 2 and 3. Adjust the AUDIO GAIN CONTROL until the test meter indicates 50 to 60 percent on normal voice inputs.
8. On the receiver panel, turn the RF GAIN switch to local, the FREQ. RESPONSE switch to narrow, the SQUELCH switch to ON, and the AVC TIME CONSTANT switch to COMM. Adjust the QUIETING and RF GAIN controls.

To Transmit

The desired preset channel may be selected by setting the CHANNEL SELECTOR switch on the transmitter panel to the desired channel, or by placing the CHANNEL SELECTOR switch in the remote position and dialing the channel number on the radio set control (fig. 9-24A). In addition, with the LOCAL-REMOTE switch on the radio set control in the remote position the channel may be selected by any one of the connected remote control units.

For voice operation, plug a microphone into the MICROPHONE JACK on the modulator-power supply panel; press the push-to-talk button to transmit; release the button to receive.

For MCW operation, plug a key into the KEY JACK on the modulator-power supply panel; set the MCW-CARRIER ON-VOICE switch to MCW to transmit; set the switch to voice when receiving.

To Receive

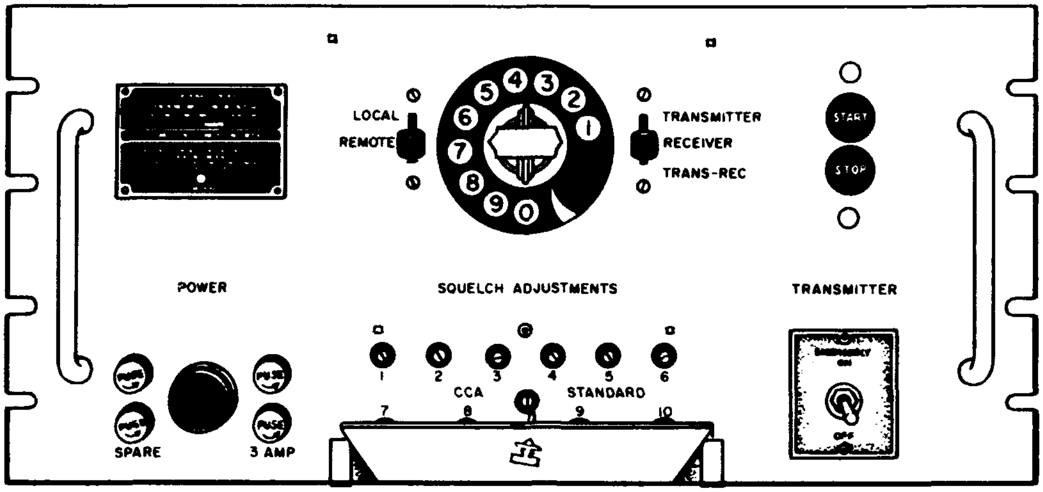
The desired channel may be selected as described for the transmitter. Plug a headset or speaker into the PHONES JACK (fig. 9-24D) and adjust the AF GAIN CONTROL. The CARRIER INDICATOR lights when a signal is present on the selected channel.

Stopping the Equipment

Turning the EMERG. switch on the radio set control (fig. 9-24A) to OFF removes all power from the set. To control the individual units, turn the POWER switches on the modulator-power supply and receiver panels to OFF. Pressing the STOP switch on the radio set control will remove power from the modulator-power supply and the transmitter.

RADIO SET AN/URC-32

Radio Set AN/URC-32 (fig. 9-25) is a manually operated radio communications transceiver for operation in the 2 to 30 mc (high-frequency) range with a transmit peak-envelope-power (pep) output of 500 watts. This transmitter is designed for single-sideband transmission, and



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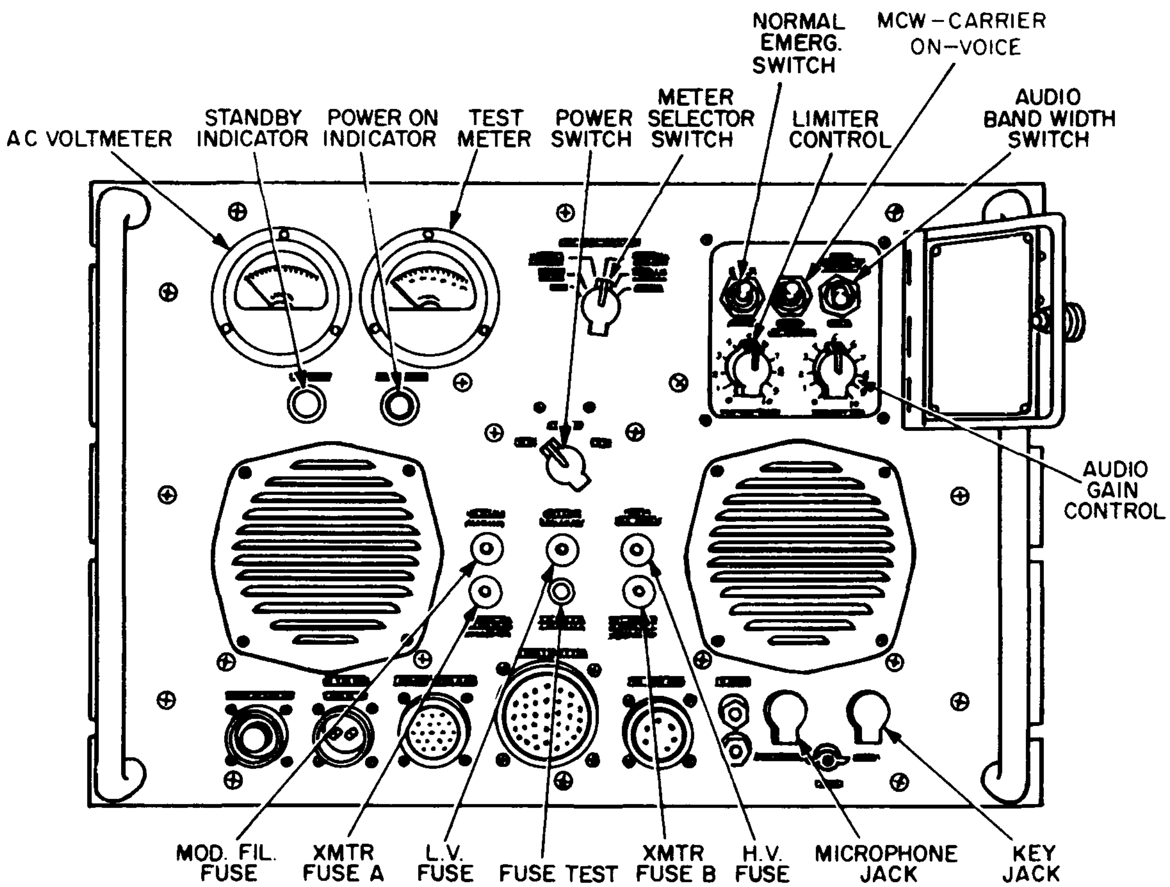

B

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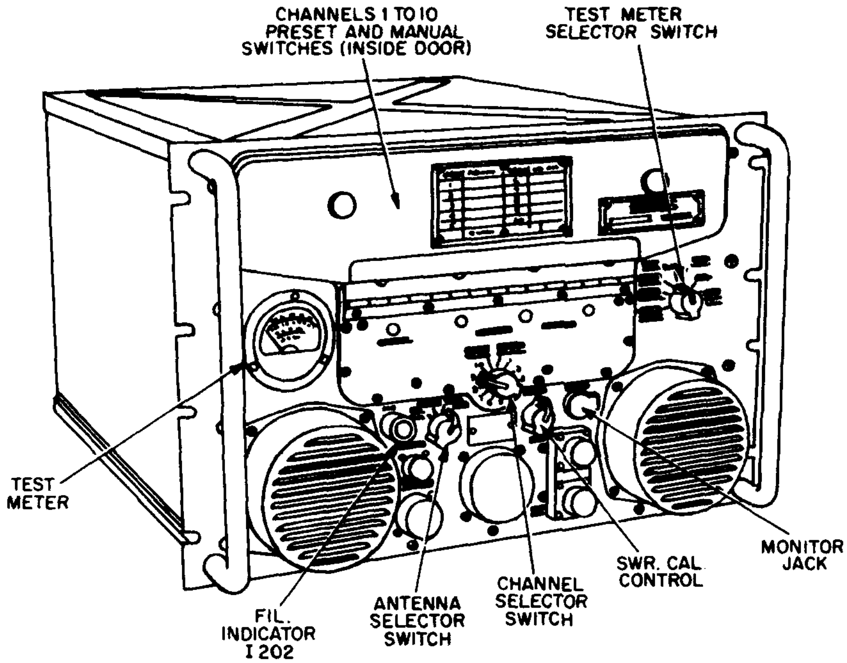
A. Radio set control C-1897/GRC-27A B. Modulator-power supply MD-129A/GR
Figure 9-24.—Radio transmitter-receiver set AN/GRC-27A, front panel controls.



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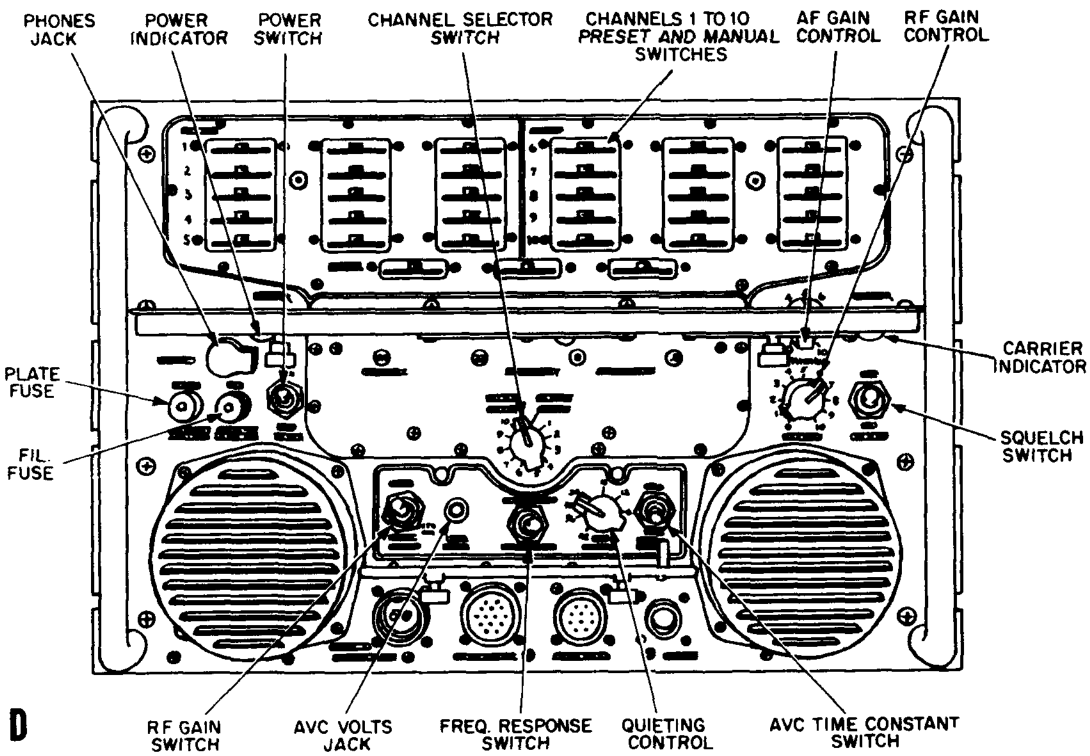

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C. Radio transmitter T-217A/GR D. Radio receiver R-278B/GR

Figure 9-24.—Radio transmitter-receiver set AN/GRC-27A, front panel controls—Continued.

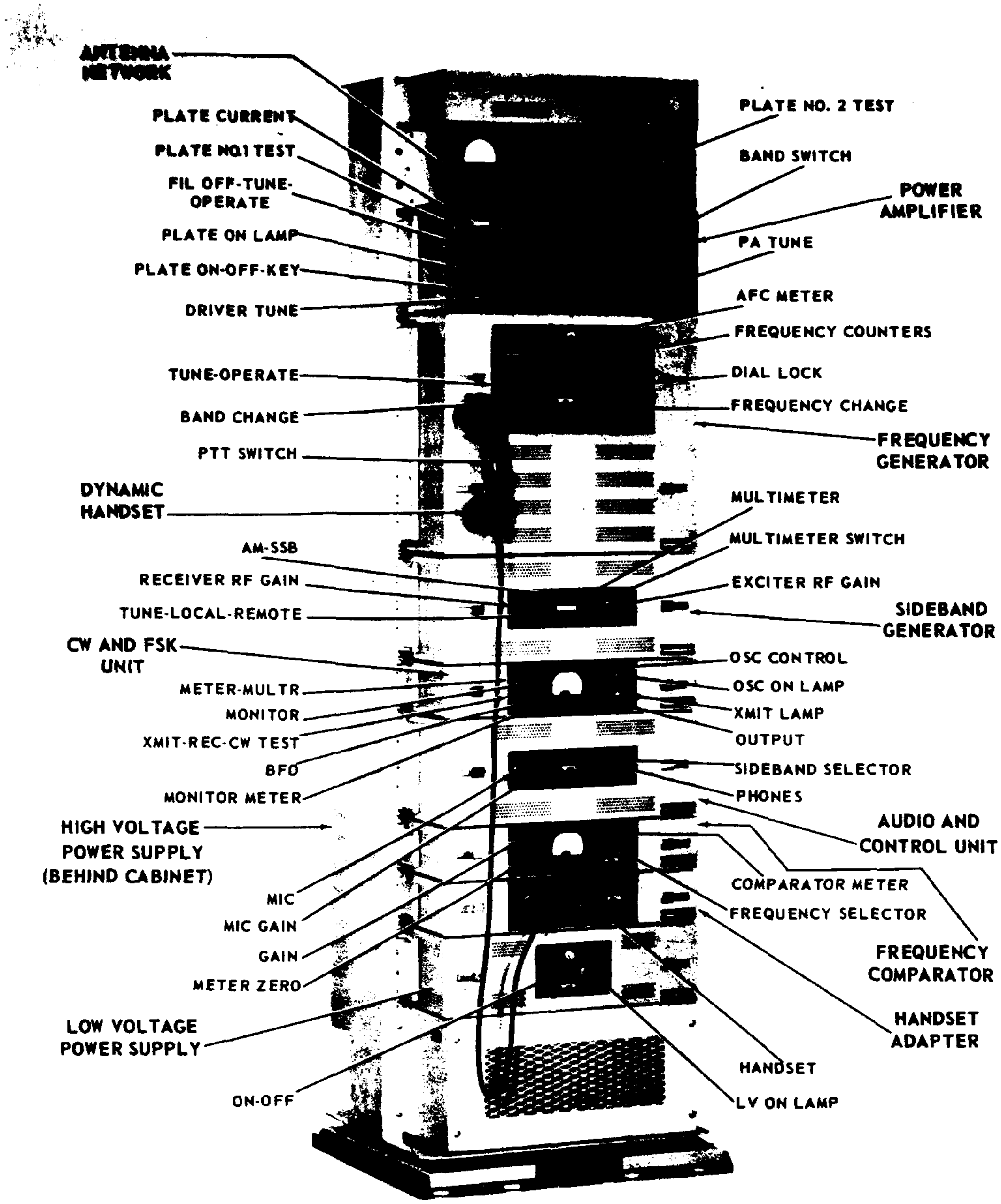

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Figure 9-25.—Radio Set, AN/URC-32, relationship of units and operating controls.

for reception on upper sideband, lower sideband, or two independent sidebands with separate audio and i-f channels for each sideband. In addition to single-sideband operation, provisions are included for a compatible a-m (carrier plus upper sideband), c-w or fsk operation.

GENERAL DESCRIPTION

The frequency range of 2 to 30 mc is covered in four bands. The desired operating frequency is selected in 1 kc increments on a direct-reading frequency counter. Frequency accuracy and stability are controlled by a self-contained frequency standard. Provisions are made for using an external frequency standard such as an AN/URQ-9.

During transmission (fig. 9-26) voice input signals from the dynamic handset are fed to the handset adapter. Input signals (c-w or remote audio) from a remote control unit (when used) are also applied to the handset adapter

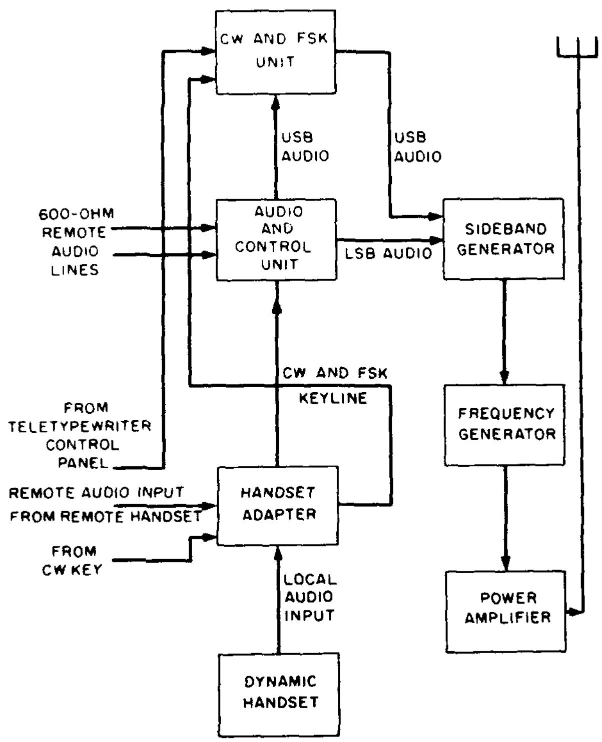

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Figure 9-26.—Radio Set AN/URC-32, transmit function block diagram.

input terminals. A local-remote switch permits the operator to select either the local audio input from the handset adapter or the remote audio input. Teletypewriter signals are applied directly to the c-w and fsk unit which provides separate audio tones for the mark and space conditions. These frequencies are later converted to the required frequency-shift signals for fsk transmission.

The output from the handset adapter is amplified in the audio and control unit. Two separate audio input paths to the audio and control unit are provided through the 600-ohm remote audio lines.

The audio and control unit amplifies the audio signals and feeds it to the sideband generator. During single-sideband voice operation (using the upper sideband) the audio and control unit output is fed through a selector switch in the c-w and fsk unit. Lower sideband transmit signals are fed directly to the sideband generator. During c-w or fsk operation, the c-w and fsk unit supplies audio tones to the sideband generator.

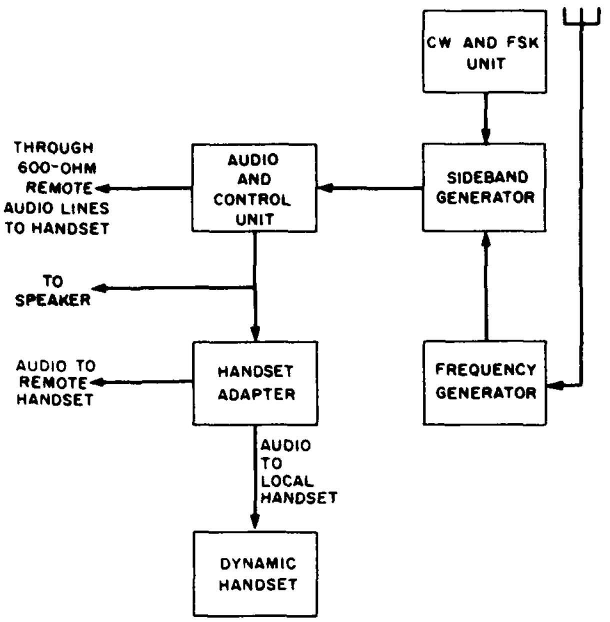
The sideband generator converts the audio input to a 300 kc intermediate frequency on the selected sideband. The modulated 300 kc output is fed to the frequency generator. This unit provides the necessary number of heterodyning processes (while preserving the signal intelligence) to produce the selected carrier frequency in the 2 to 30 mc range. The output signal is amplified in the power amplifier to the required peak-envelope-power output of 500 watts and fed to the antenna.

During the reception of modulated signals (receive operation) the antenna input signal (fig. 9-27) in the range from 2 to 30 mc is heterodyned in the frequency generator so that the output will be a modulated 300 kc signal. This signal is detected and amplified in the sideband generator, further amplified in the audio and control unit, and fed to the speaker.

During c-w reception, the c-w and fsk unit supplies a 300.550 kc signal to the sideband generator as a beat frequency for the received signal. The beat frequency can be changed over a range of ± 1 kilocycle.

AUDIO AND CONTROL UNIT BLOCK DIAGRAM

The audio and control unit (fig. 9-28) is a dual-channel amplifier which can accept audio



32.137
Figure 9-27.—Radio Set AN/URC-32, receive function block diagram.

inputs from two 600-ohm balanced lines, a 600-ohm unbalanced line, or a high impedance microphone. In the normal AN/URC-32 installation, the 600-ohm balanced lines and the dynamic microphone input are not used.

When transmitting and using the 600-ohm unbalanced input, the audio signal from the handset adapter is fed to the audio and control unit via audio transformer, T6. This input, after amplification, can be applied to the upper sideband (USB) line amplifier or to the lower sideband (LSB) line amplifier in the audio and control unit.

The sideband selector switch (fig. 9-25) controls the signal transmission and reception. With the switch in the OFF position, (fig. 9-28) the microphone amplifier circuits and the remote audio input are disconnected from the line amplifiers. This switch position also connects the upper and lower sideband audio line inputs to the line amplifiers.

With the sideband selector switch in the UPPER position, the microphone audio or remote audio is fed into the upper sideband line amplifier. The bottom sections of the switch complete the upper sideband receive circuit from the detector in the sideband generator and supplies an audio output to the speaker via the speaker amplifier circuits.

The reverse of this action happens when the sideband selector is placed in the LOWER position. When earphones (not shown) are plugged into the phone jack on the front panel the audio output normally fed to the speaker is removed.

When the sideband selector switch is in the UPPER position, the upper sideband audio is removed from the audio amplifier, A1Q101, (as discussed) and is properly terminated by R14. Resistor R15 performs the same function for the lower sideband circuits when the lower sideband is selected.

The microphone (MIC) jack, MIC GAIN control, SIDEBAND SELECTOR, and PHONES jack are located on the front panel of the audio and control unit (fig. 9-25). The microphone jack input circuits are designed for use with a high impedance dynamic microphone.

Only standard 600-ohm headphones should be connected into the PHONES output jack. The speaker output circuits (not shown) are disabled when the phones plug is inserted.

SIDEBAND GENERATOR

The sideband generator (fig. 9-25) translates audio frequencies to intermediate frequencies during transmit condition, and intermediate frequencies to audio frequencies during receive conditions.

Transmit Function

The block diagram of the sideband generator is shown in figure 9-29. The balanced modulators, carrier generator, and transmit gain control (t-g-c) circuits operate during transmit condition. The audio input to the sideband generator is taken from the secondaries of T1 and T4 on the audio and control unit (fig. 9-28) and applied to the sideband generator via T3 and T4. These transformers couple upper sideband and lower sideband audio inputs to the vox circuit and to the balanced modulators. The balanced modulators modulate a 300-kc carrier to produce separate and distinct upper and lower sideband signals with the carrier suppressed. The operation of the balanced modulator is explained in chapter 5 of this training course. The 300-kc carrier is produced in the carrier

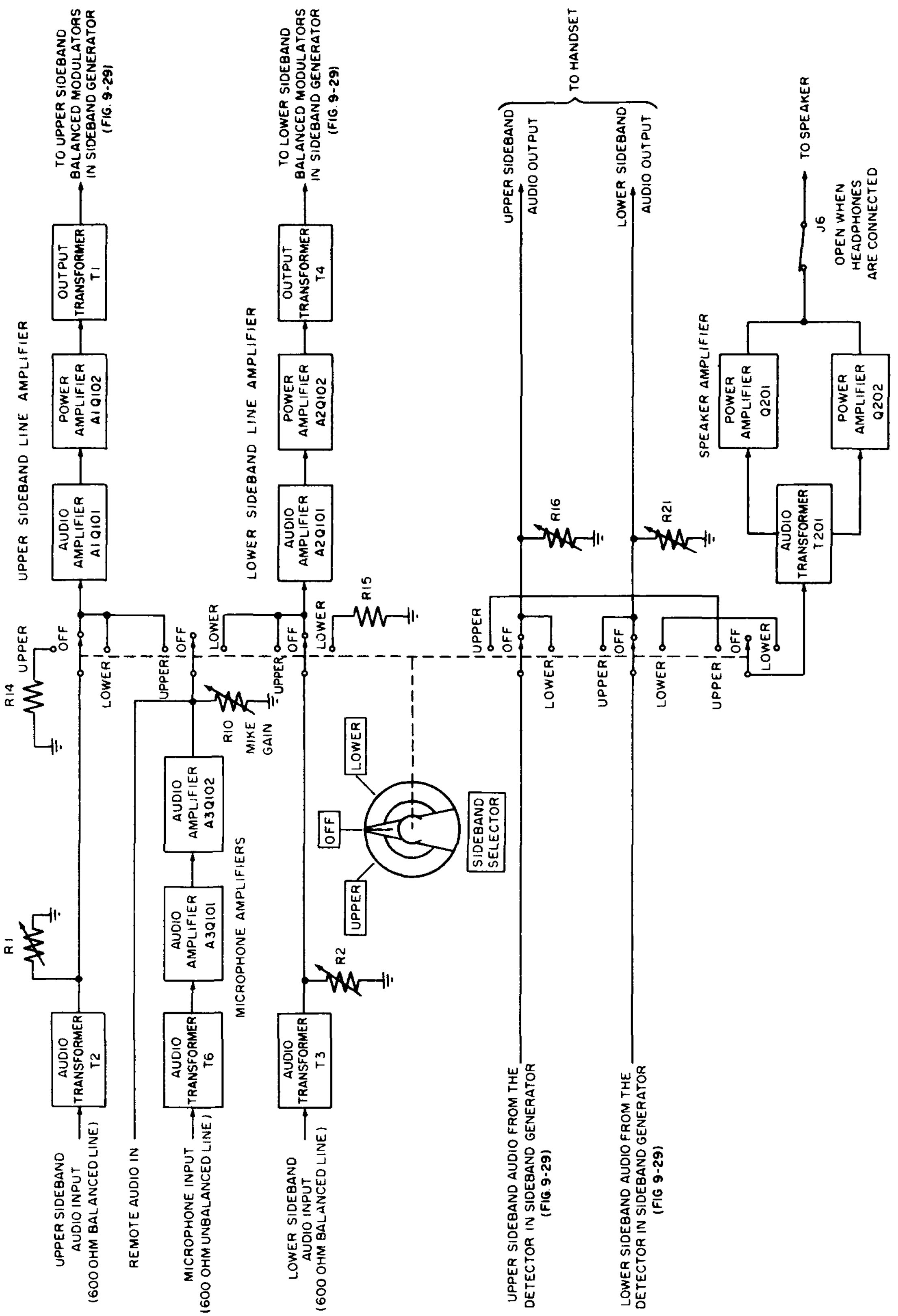


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Figure 9-28.—Audio and control unit block diagram.

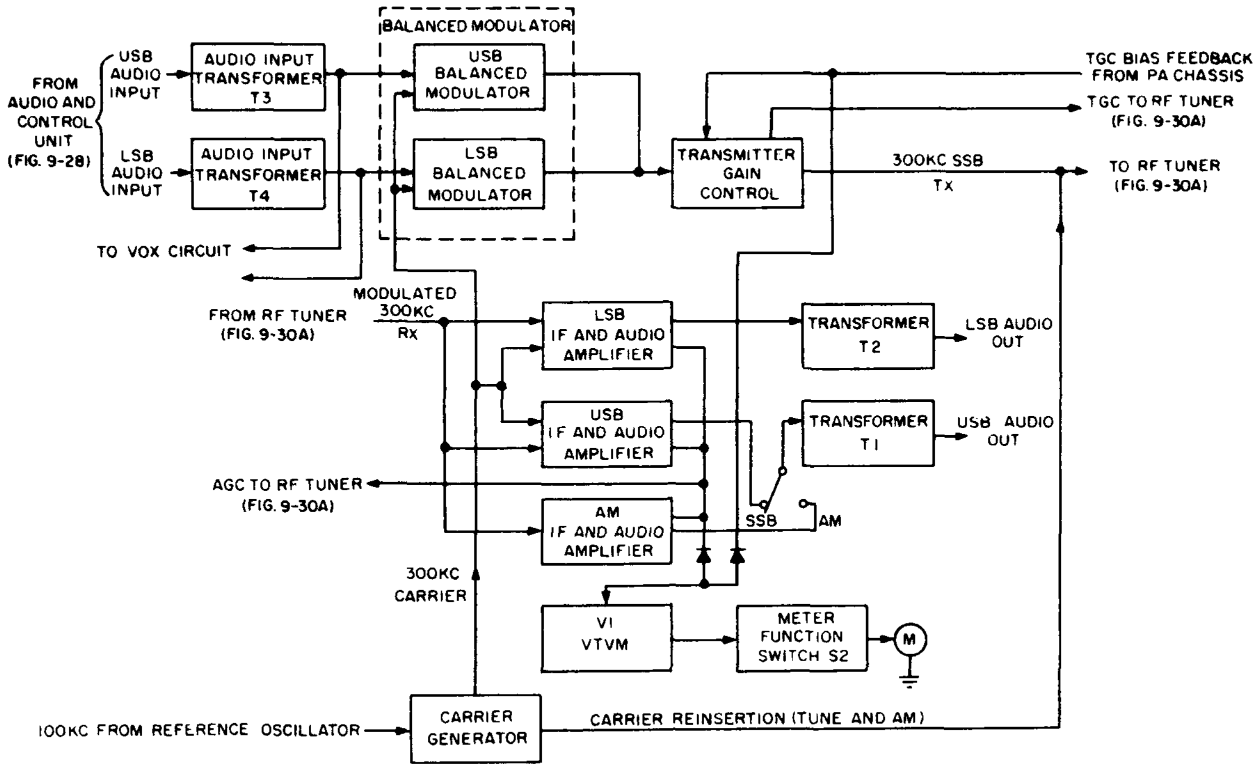

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Figure 9-29.—Sideband generator, block diagram.

generator by tripling a 100-kc reference oscillator signal from the frequency generator (discussed later).

The balanced modulator section contains two 300-kc balanced modulators. Because of a frequency inversion in the r-f tuner of the frequency generator, the lower sideband balanced modulator is followed with an upper sideband filter and the upper sideband balanced modulator is followed with a lower sideband filter. (The filters are not shown.)

The outputs of the balanced modulators are fed to the transmit gain control. The t-g-c circuit is controlled by a t-g-c voltage which is received from the power amplifier unit (not shown). This circuit maintains the 300-kc i-f output voltage at a sufficiently low level to prevent over-driving any of the subsequent stages.

The 300-kc SSB signals are fed via line TX to the r-f tuner where they are amplified and fed through the power amplifier to the antenna. During tune and a-m transmit conditions only, the unmodulated 300-kc carrier generator output is reinserted in the upper sideband signal at the output of the sideband generator. Reinsertion of the carrier at the transmitter eliminates the necessity for reinsertion at the receiver, and thus permits the use of conventional a-m receivers to receive the transmitted signal. The absence of the lower sideband does not affect the quality of the received signal. However, only one sideband plus carrier is transmitted, and the received signal is considerably weaker than it would be for double-sideband or conventional a-m operation.

Receive Condition

The i-f and audio amplifiers (LSB, USB, and AM) operate only during the receive condition to amplify the modulated 300-kc signal from the r-f tuner (via line RX). These units

also demodulate the signal and amplify the detected audio. A 300-kc carrier is reinserted into the LSB and USB I-F/A-F amplifiers from the carrier generator. A carrier reinsert adjust control permits the operator to reinsert a carrier signal which is equal in power to the sideband power at the output of the sideband generator.

When the front panel SSB/AM switch is in the AM position, the LSB, and USB I-F/A-F amplifiers are disabled. The SSB/AM switch also disables the carrier generator during a-m receive condition by deenergizing a SSB/AM relay (circuit connections not shown). The audio output from the AM I-F/A-F amplifier is fed through the SSB/AM switch in the AM position to the USB audio out line via T1. The USB I-F/A-F amplifier output is fed to T1 when the switch is in the SSB position.

The RECEIVER R-F GAIN control (fig. 9-25) controls the gain of the r-f and i-f circuits in the r-f tuner and I-F/A-F amplifiers. The EXCITER GAIN CONTROL is used to adjust the gain of the r-f amplifier circuits in the frequency generator for proper operating level. The t-g-c circuit operates in conjunction with this control to prevent a gain in the r-f stages in excess of that dictated by the gain control setting.

The TUNE-LOCAL-REMOTE switch is normally set in the LOCAL position. In the TUNE position the audio signal input circuits are disconnected, and a carrier is reinserted for tuning the power amplifier. The REMOTE position is used when a remote receiver r-f gain control and tgc-agc meter are used.

The multimeter gives an indication of the -90v, +130v, +250v, tgc-agc, or r-f output circuits as selected by the METER SELECTOR SWITCH.

CW AND FSK UNIT

The c-w and fsk unit (fig. 9-25) enables the AN/URC-32 transceiver to be operated in the c-w and fsk modes of operation. On fsk transmit operation (tone modulation), the c-w and fsk unit converts the keying input from a teletypewriter current loop to audio tones of 1,575 cps for space (no loop current) and 2,425 cps for mark (loop current). On c-w transmit operation (actually mcw) the unit provides a keyed audio tone of 1,000 cps or 1,500 cps as selected by the OSC control switch.

During fsk receive operation, the c-w and fsk unit provides a bfo (beat-frequency oscillator) signal which is required for c-w reception. This signal is centered on 300.550 kc and is variable approximately 1 kc above or below this frequency.

The monitoring circuit contains a meter, M1, which is used for monitoring the receive and transmit audio outputs of the audio and control unit, and for monitoring the output of the c-w and fsk unit.

The function of the c-w and fsk unit is determined by the position of the oscillator control switch, which is located on the front panel. In the OFF position, a section of the switch disables the c-w and the fsk unit by removing the B+ voltage (+130v) from the circuits. Another section connects the USB transmit audio input line from the audio and control unit to the USB transmit audio output line. This line is connected to the USB balanced modulators of the sideband generator, which, in turn, feeds the transmit circuits. Thus, in the OFF position, the c-w and fsk unit circuits are deenergized, and the voice input signals from the handset are transmitted.

When the OSC control switch is in the FSK position, teletypewriter signals will be fed through the transmitter. In the final two positions of the switch, c-w signals are transmitted.

FREQUENCY GENERATOR

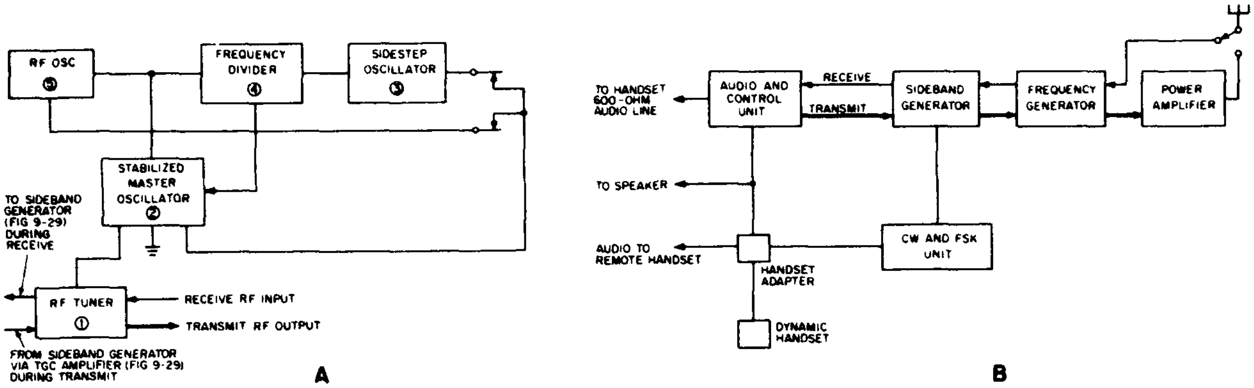
The frequency generator (fig. 9-25) produces the desired radio frequency as determined by the settings of the BAND CHANGE and FREQUENCY CHANGE controls. This unit also provides frequency control and r-f amplification for either transmit or received signals.

The frequency generator block diagram (fig. 9-30A) shows that this unit consists of a main chassis and five plug-in units. These units include the:

1. R-f tuner
2. Stabilized master oscillator (SMO)
3. Sidestep oscillator (optional)
4. Frequency divider
5. Reference oscillator or isolation amplifier

The path of the signal through the various transmitter units during TRANSMIT condition is indicated by the heavy lines in figure 9-30B. The RECEIVE signal path is indicated by the light lines.

The r-f tuner of the frequency generator (fig. 9-30A) is an i-f to r-f translator during transmit condition, and an r-f to i-f translator during receive condition. During the transmit



(A) Frequency generator
(B) AN/URC-32 Transceiver

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Figure 9-30.—Block diagram.

condition, the r-f tuner accepts the 300-kc single sideband signal from the balanced modulators of the sideband generator via the t-g-c circuit, and translates it to the desired frequency (in 1 kc steps) ranging from 2.0 to 30.0 mc.

During receive condition, the r-f tuner accepts and amplifies the selected signal from the antenna (as indicated on the band dial) and translates it to a 300-kc i-f signal. This signal is fed to the I-F/A-F amplifier of the sideband generator (or AM I-F/A-F amplifier depending on the type of reception) for demodulation and amplification.

The names of the controls on the frequency generator front panel are indicative of their function.

POWER AMPLIFIER

The power amplifier (fig. 9-25) is a two-stage r-f power amplifier which amplifies the 0.15 watt PEP signal from the frequency generator to a nominal output power of 500 watts PEP. It contains a driver stage, a power amplifier stage, a t-g-c rectifier, a bias and filament supply, and the necessary control and interlock circuits.

The driver and power amplifier plate circuits are manually tuned (by the DRIVER TUNE and PA TUNE controls, respectively) through the frequency range from 1.7 to 31.7 mc in 4 bands. The power amplifier plate circuit uses a tuned pi network to obtain an unbalanced 50-ohm output impedance over the complete range of frequencies.

The controls, switches, and meters on the power amplifier and their function are as follows:

1. PL NO.1 TEST—Test switch to disconnect one of the power amplifier tubes while checking power amplifier tube balance. PL NO. 2 Test is used to disconnect the other PA tube while performing this check.
2. PLATE CURRENT METER—Test meter to indicate plate current drawn by the power amplifier tubes.
3. FIL OFF-TUNE-OPERATE SWITCH—The different positions and their function are:
   a. FIL OFF—Disables power amplifier and the high voltage power supply.
   b. TUNE—Reduces the power amplifier voltages for tuning.
   c. OPERATE—Normal operating position.
4. PLATE ON-OFF KEY—The different positions and their function are:
   a. ON-OFF—Controls application of plate and screen voltage to the power amplifier tubes.
   b. KEY—Performs same function as the ON position plus keying the transmitter.

5. DRIVER TUNE—Tunes the driver amplifier plate circuit.
6. PA TUNE—Tunes the power amplifier plate circuit.

OPERATING PROCEDURE

The following preliminary settings must be performed before turning on the equipment:

Low-Voltage Power Supply	ON-OFF switch to OFF.
Power Amplifier . .	FIL OFF-TUNE-OPERATE switch to FIL OFF.
	PLATE switch to OFF.
Sideband Generator	RECEIVER RF GAIN control counterclockwise.
	EXCITER RF GAIN control counterclockwise.
	TUNE-LOCAL-REMOTE switch to LOCAL.
Frequency Comparator	FREQUENCY SELECTOR switch to OFF.
CW and FSK Unit	XMIT-REC-XMIT TEST switch to REC. OSC CONTROL switch to OFF.
Audio and Control Unit	MIC GAIN control counterclockwise. SIDEBAND SELECTOR switch to OFF.

TURNING ON EQUIPMENT

The following procedure is used to apply power to the equipment. If the equipment is to be used only as a receiver, perform only steps a and b.

a. Set OFF-ON switch on Low-Voltage Power Supply to the ON position. The indicator lamp on Low-Voltage Power Supply will light when air pressure is present in the cooling system.

b. Set the meter selector switch on Sideband Generator to the -90, +130, and +250 positions and check that the meter reads between 35 and 50 db in each position.

c. Turn the FIL OFF-TUNE-OPERATE switch on Power Amplifier to the OPERATE. Wait 30 seconds before performing step d.

d. Depress the PLATE switch on the Power Amplifier to KEY and check that PLATE CURRENT meter on Power Amplifier reads 150 ma of static plate current. PLATE lamp on Power Amplifier HV ON lamp on High-Voltage Power Supply, and XMIT lamp on CW and FSK Unit should light.

e. Depress PLATE switch to KEY and alternately depress PLATE NO. 1 TEST switch and PL NO. 2 TEST switch on the Power Amplifier, checking that the PLATE CURRENT meter reads between 60 and 90 ma of static plate current for each tube.

f. Operate PLATE switch on Power Amplifier to ON. PLATE LAMP on Power Amplifier and the HV ON lamp on High-Voltage Power Supply should light.

TUNING PROCEDURE

The following tuning procedure is used whenever the AN/URC-32 is set to a new operating frequency:

a. Set PLATE switch on Power Amplifier to OFF.

b. Set BAND CHANGE switch on the Frequency Generator to the desired frequency band. The band indicator lamp will light over the selected frequency counter. The AN/URC-32 frequency bands are as follows:

Band 1	2.0 to 3.7 mc
Band 2	3.7 to 7.7 mc
Band 3	7.7 to 15.7 mc
Band 4	15.7 to 30.0 mc

c. Release DIAL LOCK on the Frequency Generator. Set the desired operating frequency on the lighted frequency counter using the FREQUENCY CHANGE control. When selecting a frequency which is not on the band 7.7-15.6 mc, or 15.7-to 30.0 mc frequency counters, set the frequency counter to the next lower frequency on the counter and set the BAND CHANGE switch to ADD 1, ADD 2, or ADD 3. When the desired

operating frequency is on the frequency counter, set the BAND CHANGE switch to ADD 0. EXAMPLE: To select an operating frequency of 23.699 mc, set the BAND CHANGE switch to BAND 4, set the 15.7- to 30.0-mc frequency counter to 23.696 mc using the FREQUENCY CHANGE control, and reset the BAND CHANGE switch to BAND 4 ADD 3.

When setting up a frequency on any band, make certain the white index line on the last dial of the 15.7- to 30.0-mc frequency counter is centered in the window.

d. Reset DIAL LOCK and momentarily depress the TUNE-OPERATE switch on Frequency Generator to TUNE. This prevents the stabilized master oscillator from locking on spurious signals. The AFC meter shows the amount of correction being supplied to the master oscillator from the stabilization circuits and should not be expected to read 0 unless the master oscillator is exactly on frequency and no correction is required.

e. Adjust RECEIVER RF GAIN control so that the AGC does not increase the gain excessively between characters in CW and FSK or between words in single-sideband voice reception. The RECEIVER RF GAIN control is normally set so that the sideband generator meter (AGC) "kicks up" about 15 db with the meter switch in the TGC-AGC position. If speaker, handset, or remote audio output level is not adequate, set SPEAKER GAIN control (under dust cover of Audio and Control Unit) for desired output level. On FSK operation, adjust BFO control for proper operation of FSK converter. This completes tuning of the receiver portion of the AN/URC-32.

Before performing the following steps, the AN/URC-32 must be connected to an antenna system containing an antenna tuner control such as the AN/SRA-22 or 180U-2 and a dummy load such as the 172J-1. These antenna tuners contain a directional wattmeter and switch for selecting the antenna or the dummy load. On installations which use the 180U-2 and an antenna tuner such as the AN/BRA-3, AN/BRA-5, AN/SRA-18, or a 50-ohm multicoupler, set the couple control power switch to ON and the tuner bypass switch to OFF. The ready light must also be on. Unless this is done, the interlock circuits of the antenna tuner will prevent operation of the AN/URC-32 power amplifier.

f. Set the ANT-LOAD switch on the antenna tuner control to LOAD. Set the FIL OFF-TUNE-OPERATE switch on Power Amplifier to TUNE. Set the meter selector switch on the Sideband Generator to RF OUT. Set TUNE-LOCAL-REMOTE switch on the Sideband Generator to TUNE.

In the following steps, key to transmit by depressing the PLATE switch on the Power Amplifier 367A-3 to KEY.

g. With the EXCITER RF GAIN control in the maximum counterclockwise position, key to transmit and turn EXCITER RF GAIN control clockwise until meter on the Sideband Generator 786F-1 reads approximately 40 db.

h. Key to transmit and adjust DRIVER TUNE control on the Power Amplifier within the desired band limits to peak the PLATE CURRENT meter reading, adjust the EXCITER RF GAIN control as necessary to maintain a PLATE CURRENT meter reading of approximately 200 milliamperes. The red index on the DRIVE TUNE control must fall within the proper band limits marked on the panel. If a power output reading is observed on the power output meter of the antenna tuner, detune the P. A. TUNE control until no power output is indicated. This effectively disables the r-f feedback so that optimum adjustment of the driver plate circuit can be obtained. Reducing EXCITER RF GAIN control for a decrease in PLATE CURRENT meter reading, as necessary, will result in a sharper indication of driver tuning.

After completing step h, make no further adjustments on the DRIVER TUNE control for the remainder of the tuning procedure.

i. Set the P. A. TUNE control on the Power Amplifier within the desired frequency band limits. Key to transmit and adjust P. A. TUNE control for a dip in the PLATE CURRENT meter reading.

j. Set EXCITER RF GAIN control maximum counterclockwise. Set FIL OFF-TUNE-OPERATE switch on the Power Amplifier to OPERATE.

k. Key to transmit, turn EXCITER RF GAIN control clockwise until 500 watts of forward power is indicated and redip PLATE CURRENT meter reading using the P. A. TUNE control. The PLATE CURRENT meter reading should not exceed 500 milliamperes.

DO NOT OPERATE ANT-LOAD SWITCH WHILE AN/URC-32 IS KEYED TO TRANSMIT.

l. Set ANT-LOAD switch on antenna tuner control to ANT and adjust antenna tuner controls for minimum reflected power. For this procedure see the operating

procedures in the antenna tuner control technical manual.

m. Key to transmit and adjust EXCITER RF GAIN control for a forward power output meter reading of 500 watts. The reflected power meter reading should be less than 10 watts. The PLATE CURRENT meter reading should be between 450 and 550 milliamperes.

n. Key to transmit and adjust the EXCITER RF GAIN control for a forward power output of 125 watts.

o. Key to transmit and check the following meter readings:

PLATE CURRENT. . . . meter	Approximately 300 ma
Forward power. . . . . . output	125 watts.
Reflected power	Less than 3 watts
Sideband Generator . . . meter RF OUT	10 to 20 db
Sideband Generator . . . meter TGC	0 db

p. Set TUNE-LOCAL-REMOTE switch on the Sideband Generator to LOCAL. On AM transmit operation, readjust EXCITER RF GAIN control for 125-watts forward power. Set PLATE switch on the Power Amplifier to ON. This completes the tuning procedures.

CHAPTER 10

COMMON OPERATING ADJUSTMENTS— TELETYPE AND FACSIMILE

Teletype and facsimile principles were discussed in chapter 5. This chapter will discuss representative equipments installed aboard ships. Principles of operation, and common operating adjustments will be presented.

TELETYPE EQUIPMENT

A radio teletype system consists of series connected transmitting and receiving loops depending upon the setting of the SEND-REC. switch in the control unit (fig. 10-1). With the SEND-REC. switch in the receive position, the receiving loop includes the page printer (teletypewriter), power supply, teletype panel, converter-comparator, and the control unit. During frequency-shift keying, the transmitting loop includes the page printer, power supply, teletype panel, frequency-shift keyer, and the control unit with the switch in the position shown. When the switch is set to the S/R tone position, the transmitting loop is completed through the tone converter.

A single power supply PP-765/U provides current for the selected series loop. Six teletypewriter systems may be operated from the

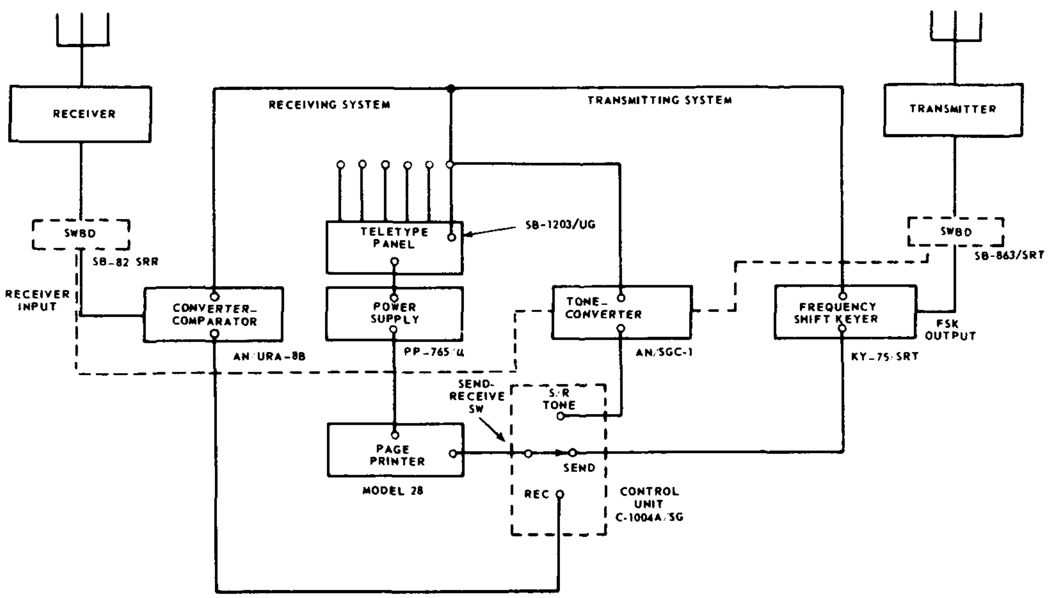

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Figure 10-1.—Block diagram of a representative radio teletype system.

power supply through connections to the teletype panel.

FREQUENCY-SHIFT KEYER KY-75/SRT

The primary purpose of Frequency-Shift Keyer KY-75/SRT (fig. 10-2) is to replace the conventional exciter of a c-w transmitter with a source of r-f excitation that can be shifted a small amount upward or downward to produce r-f teletypewriter or facsimile signals corresponding to the d-c teletypewriter or facsimile signals connected to the input of the keyer.

The output of the keyer can be applied to any existing c-w transmitter capable of operating from a 2- to 20-volt excitation source, for passage through class C amplifier or multiplier stages. The keyer is used principally for comparatively long-distance communications in the high-frequency range. The frequency range of the keyer output signal is from 1 to 6.7 megacycles. Rated power output is 6 watts into a 75-ohm resistive load.

The frequency range is selected by a three-position band switch with calibrated frequency ranges of 1 to 1.8 megacycles, 1.8 to 3.5 megacycles, and 3.5 to 6.7 megacycles. A four-position switch is provided for selection of one of three crystals; the fourth position is provided to permit the use of an external oscillator with the KY-75/SRT. The frequency shift capabilities of the keyer for photo transmission provide a total range of zero to 2000 cycles so that the transmitter frequency may be adjusted to any value from zero to 1000 cycles higher than or 1000 cycles lower than the assigned frequency.

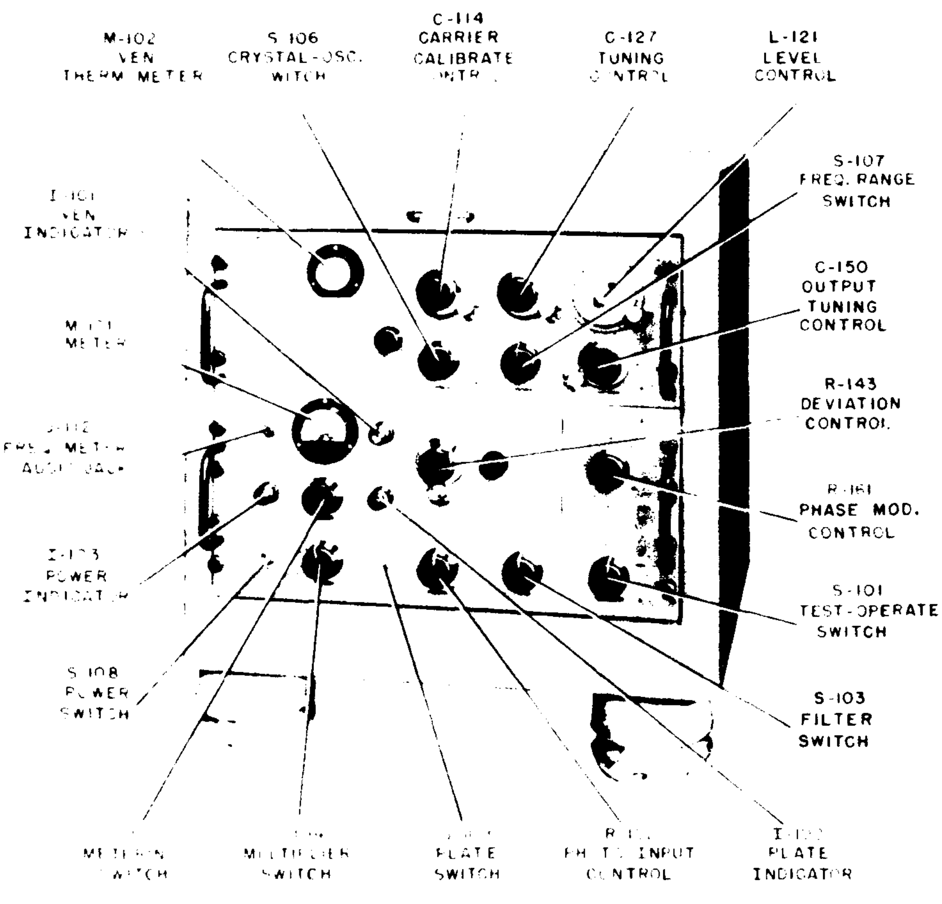

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Figure 10-2.—Frequency-shift keyer KY-75/SRT, front panel compartment identification.

A block diagram of the frequency-shift keyer is illustrated in figure 10-3. There are three functional subdivisions. These include (1) the r-f circuits, (2) the modulator circuits, and (3) the power supply. The r-f circuits comprise the crystal oscillator, V-110; the low frequency oscillator, V-107; the balanced reactance modulator, V-106, the buffer amplifier, V-111; the final power amplifier, V-112; the balanced mixers V108 and V109; and the output circuits. The modulation circuits comprise the test-operate and calibration circuit; the photo-input control, R-102; pulse limiters, V-101 and V-102; phase-modulation oscillator V-105; phase modulation control R-161; cathode followers V-104 and V-103; pulse shaper; deviation dividers; and deviation control R-143.

The test-operate calibrate switch is a five-position switch used to select the circuit arrangement required for frequency-shift or photo operation and the arrangement required to perform the alignment adjustments for carrier, mark, and space signals.

The power supply includes a full-wave rectifier stage, V-116; three voltage regulator stages V-113, V-114, and V-115; and an a-c filament current regulator stage, V-117.

Operating adjustments for the KY-75/SRT will be discussed along with facsimile equipment later in this chapter. Late models of Navy transmitters have built-in keying circuits for frequency-shift operation, and do not require an external keyer for either teletype or facsimile transmission.

CONVERTER-COMPARATOR GROUP AN/URA-8B

The Frequency-Shift Converter-Comparator Group AN/URA-8B comprises two Frequency-Shift Converters CV-89A/URA-8A and one Comparator, CM-22A/URA-8A, as illustrated in figure 10-4. In diversity reception the audio outputs of two standard Navy receivers (like the AN/SRR-12) are fed to their associated frequency-shift converters, as shown in the block diagram of fig. 10-5. The d-c signals from the discriminator circuits of the two frequency-shift converters are compared in the mark space selector circuit of the comparator which automatically selects the better mark and the better space pulse for each character. The second frequency-shift converter is identical to the first and is represented by a single block for simplicity. The receivers may be operating on space diversity (if shore based) or frequency diversity (if aboard ship) on any radio frequency within their ranges. The frequency-shift converter is described first. The comparator is then described briefly, and common operating adjustments are emphasized last.

Frequency-Shift Converter

Each frequency-shift converter includes (1) a discriminator subunit, (2) oscillator-keyer subunit, (3) monitor subunit, (4) power-supply subunit, (5) cable-filter assembly, (6) blower subunit, and (7) chassis-panel assembly (Fig. 10-5).

The discriminator subunit contains wide-shift (200 to 1000 cycles) and narrow-shift (10 to 200 cycles) filters, a discriminator circuit, slow-speed (60 words per minute or less) and fast-speed (more than 60 words per minute) filters, and an axis d-c restorer circuit. The discriminator converts frequency variations into corresponding voltage variations as illustrated in figure 10-6.

Low pass filters attenuate spurious signals above the frequency of the desired pulse-rate to prevent faulty operation due to noise, harmonics and so forth.

The axis restorer maintains the optimum axis, or bias, for keying nonsymmetrical signals and reinserts the d-c component of the signal required for relay tube operation. It produces an optimum output signal when the received signal is heavily biased, either mark or space. It will lock up (close) the teletype loop circuit when a prolonged mark or space signal condition develops to prevent the teletypewriter from running open. The setting of the threshold control affects the time required to lock up the teletype loop circuit.

The oscillator-keyer subunit contains the circuits for keying the teletype d-c loop and operating the teletype printers. It also provides a keyed-tone output by keying a Tone Modulator, which may be selected as any one of eight audio frequencies. Provision is made for the injection of an external tone, if desired.

The oscillator-keyer subunit circuits are used in single receiver operation; but in diversity reception the signal from the converter is taken directly from the low-pass filter (after the discriminator) and fed to the comparator without using the tone and output circuits of the oscillator-keyer subunit. These are available, however, if it is desired to use the

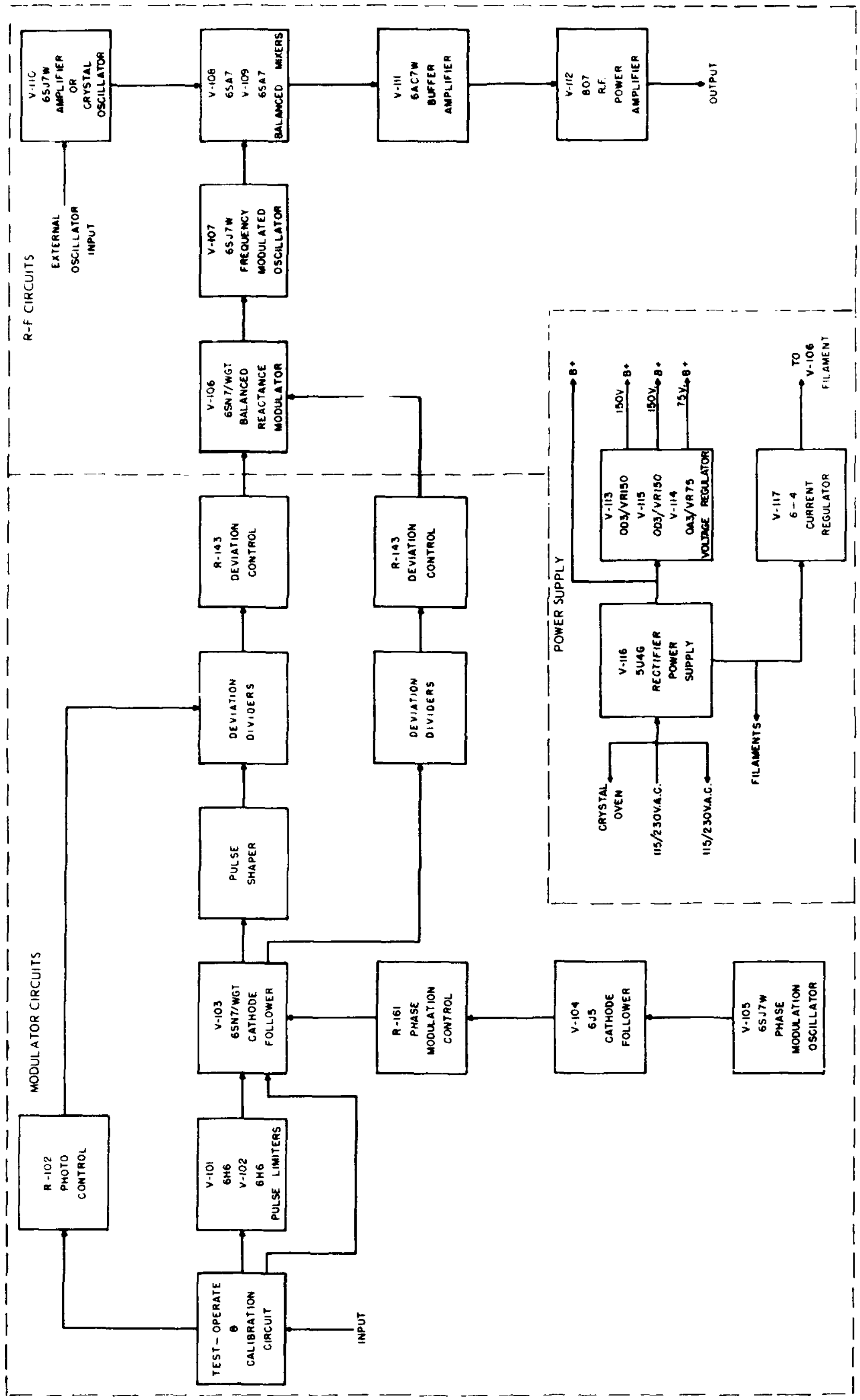

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Figure 10-3.—Block diagram of frequency-shift keyer KY-75/SRT.

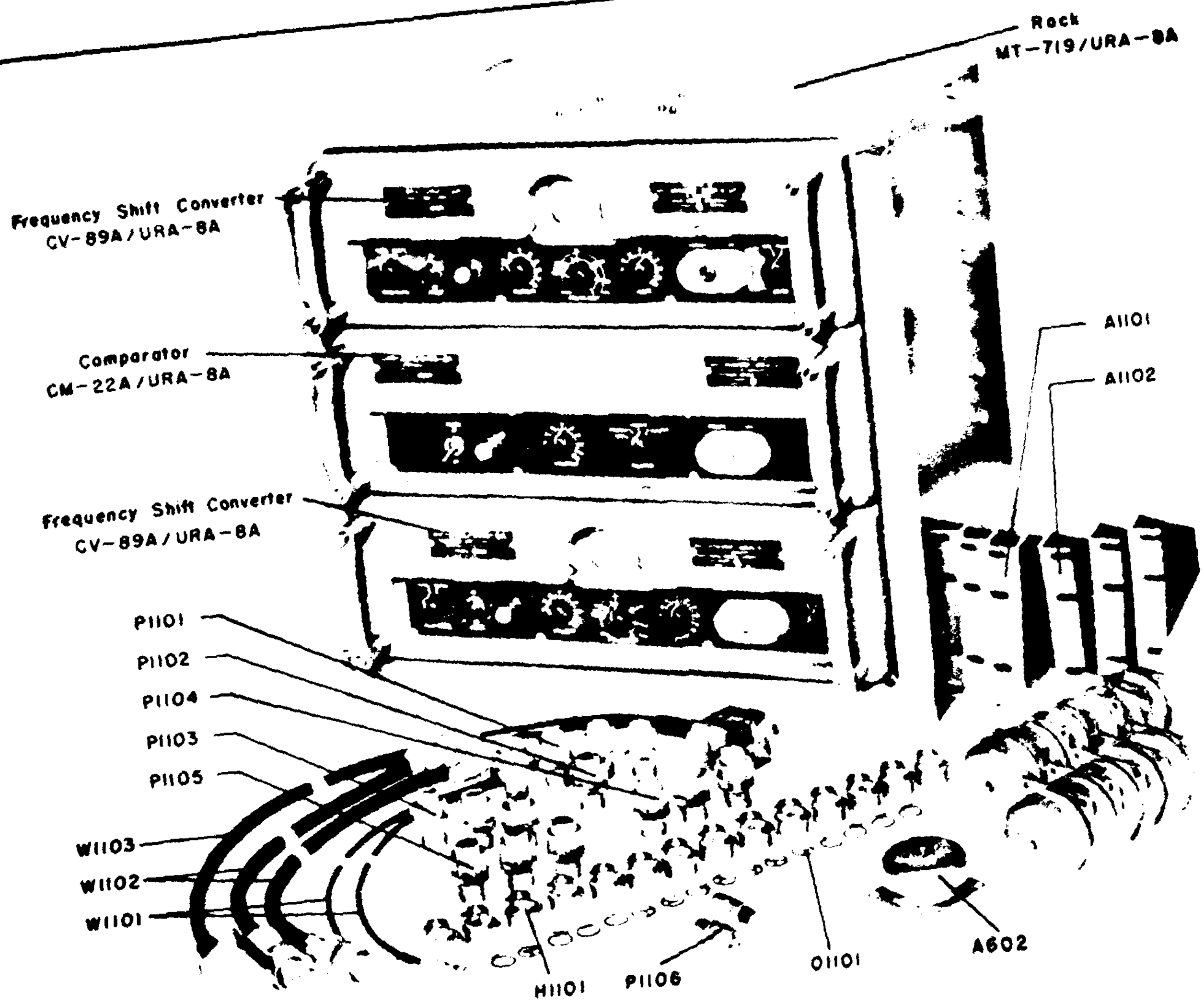

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Figure 10-4.—Frequency-shift converter-comparator group AN/URA-8B.

signal from one channel of the system while operating in diversity reception.

The monitor subunit includes a 2-inch cathode-ray oscilloscope used as a monitor for indicating proper tuning of the receiver, for checking the approximate width of the frequency shift of the signal, and for observing the polarity of the mark-space characters and other details of the signal. It employs a 60-cycle, sine-wave sweep. The vertical amplifier gain control is calibrated in cycles of shift, which are represented by a full pattern between horizontal lines marked on the screen window. The customary oscilloscope controls are provided. An external connection is provided for using a remote monitor or test oscilloscope.

The power supply subunit furnishes all the power required by the other subunits of the frequency-shift converter and is designed to operate from a power source of 105/115/125 volts, 50 to 60 cycles, single phase. A link connector is provided for selecting the correct transformer tap for the particular voltage being used.

The cable filter assembly carries all the connections to the circuits of the chassis-panel assembly and its subunits. On the rear of the cable-filter assembly are ten connectors: one for blower power, and nine extending (in a row) out through the back of the case for accommodating all input and output connections to the frequency-shift converter.

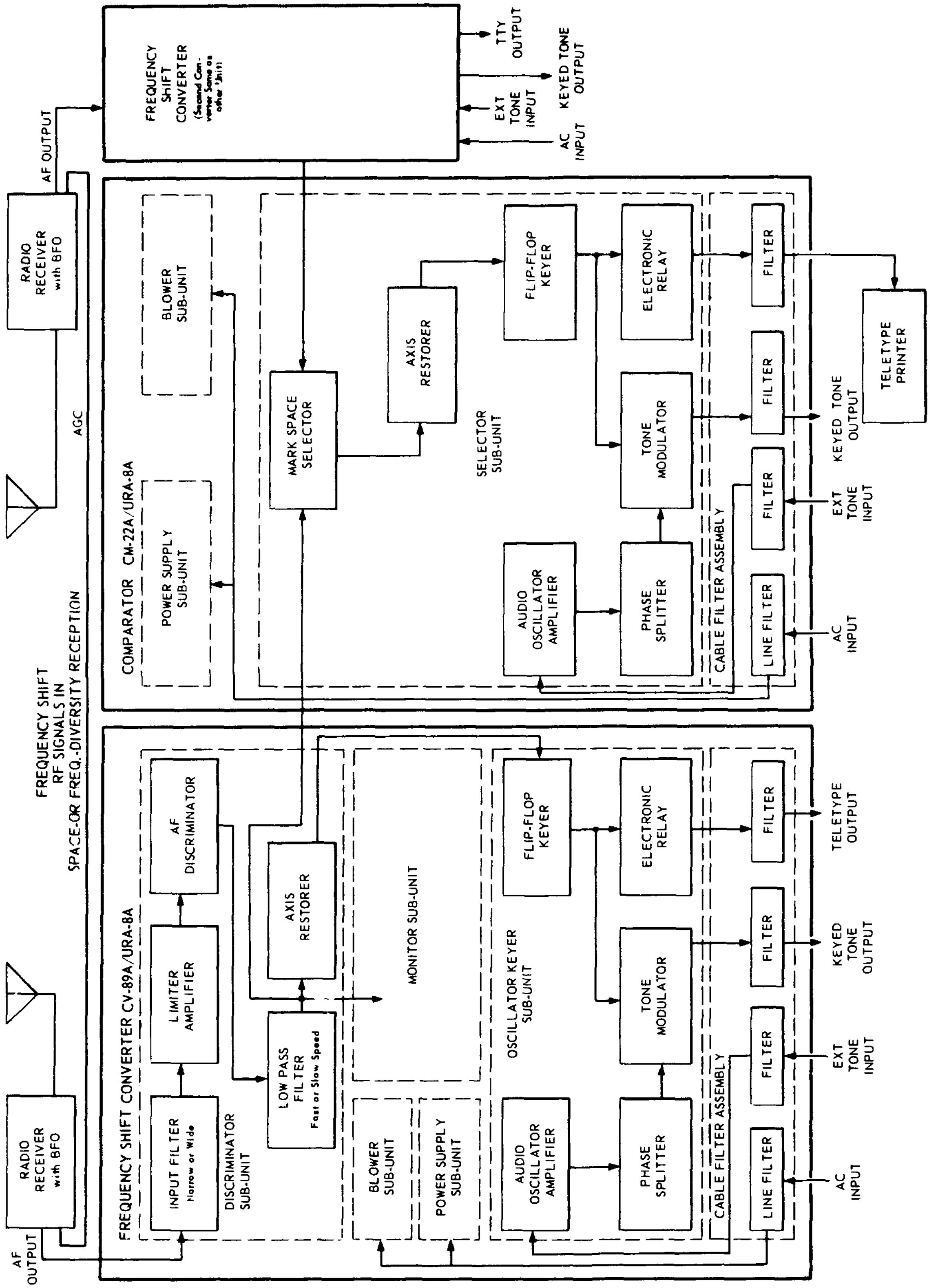

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Figure 10-5. —Block diagram of frequency-shift converter-comparator group AN/URA-8B.

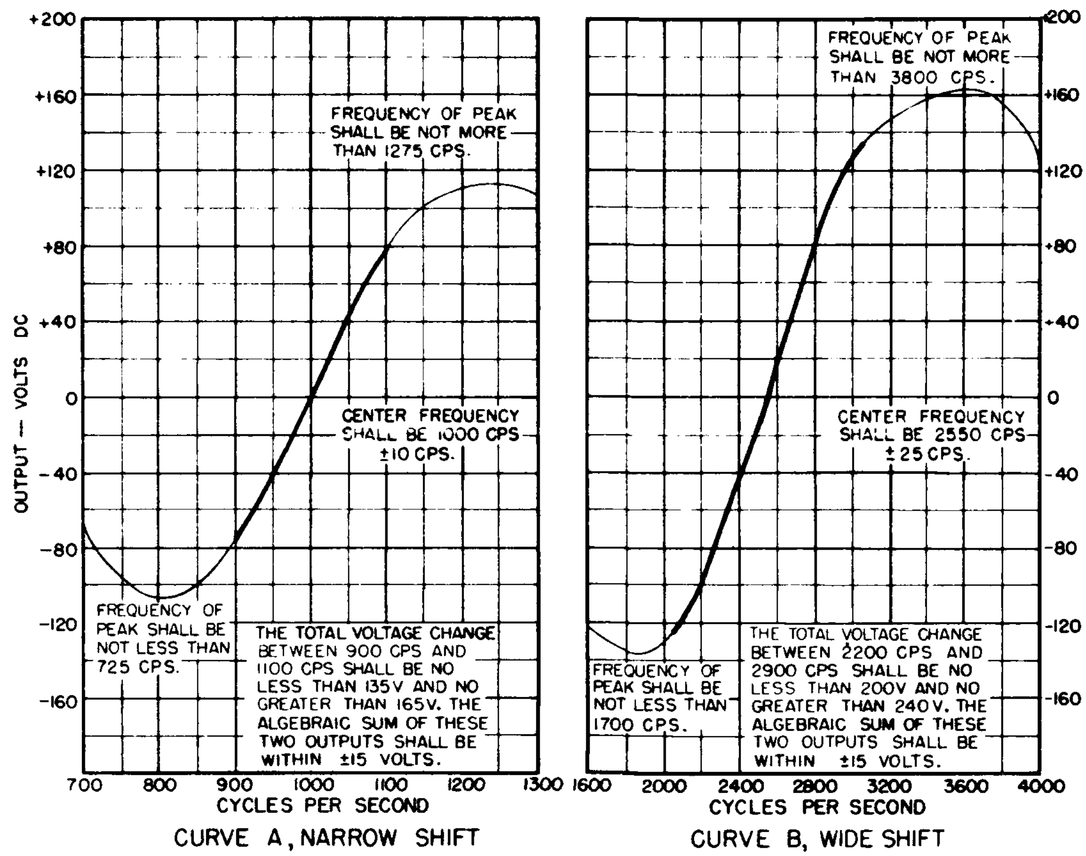

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Figure 10-6.—Discriminator frequency response curves.

The cable filter assembly removes extraneous noise and other signals, which might cause errors in keying. It includes r-f filters for the a-c input, the teletype output, the tone output, and the external tone input circuits.

The blower subunit is mounted on the rear of the case. It forces air through the unit for ventilation when the equipment is being used in high-temperature spaces. The motor operates on 110 volts, 60 cycles, and receives its power by way of a connector on the cable filter assembly. The air intake opening of the cast aluminum housing is covered by an air cleaner, which has an aluminum cloth filter pad. Just inside this opening is a thermostatic switch, which automatically closes to start the motor when the temperature exceeds approximately 49° C.

The chassis-panel assembly consists principally of the front panel and a skeleton chassis into which the four previously described subunits are plugged and mounted. It has cabled wiring carrying the circuits between the receptacles for the subunits and cable filter assembly and to the electrical components on the front cable. The front panel components include the a-c power switch, the pilot light, and two monitor jacks. Other controls and indicators are described under "operation."

Comparator

The Comparator CM-22A/URA-8A (Fig. 10-5) includes (1) a selector subunit, (2) a power-supply subunit, (3) a cable-filter assembly, (4) a blower subunit, (5) a chassis-panel assembly, and (6) a case.

The selector subunit contains the circuit that compares the simultaneous signals from the two frequency-shift converter units and

selects the best mark pulse and best space pulse for each character in the signals. The portion of the selector subunit in which this action occurs is illustrated in figure 10-7.

For example, assume that the first converter delivers a 3-volt positive pulse with respect to ground at the same time that the second converter delivers a 2-volt positive pulse. The 3-volt positive pulse will pass through V1A with negligible drop and develop 3 volts across R1. (Assume that the lower end of R1 is at or near ground potential.) This action makes the cathode of V2A 3 volts positive to ground; but the signal from the second converter is only 2 volts positive to ground. Hence V2A is cut off (its plate is negative with respect to its cathode), and only the diode with its plate positive with respect to its cathode will pass the signal. Thus in this example the signal from the first converter is selected by the comparator. The same selection occurs for the negative pulses at V1B and V2B; these pulses have R2 as their common load resistor.

When the signals from the two converters have equal magnitudes, there is some combining in the selector subunit due to phase difference, but otherwise the circuits pass only the stronger mark (positive) or the stronger space (negative) pulse. The selection is instantaneous even to the selection of parts of poorly shaped pulses.

Following the mark-space selector is an axis restorer similar to that in each frequency-shift converter, after which the keying, tone, and output circuits are identical to those in the frequency-shift converter. The selected mark-space pulses are used by these circuits to key the teletype d-c loop and produce the keyed tone output.

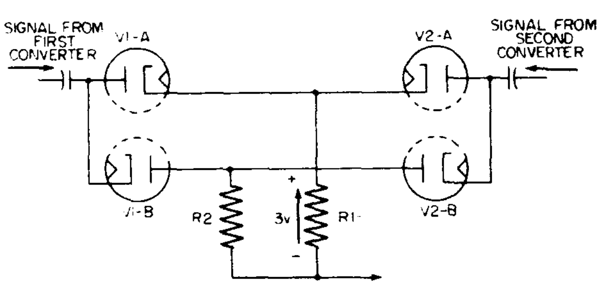

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Figure 10-7.—Portion of selector subunit in comparator CM-22A/URA-8A.

The power supply unit supplies the power required to operate the selector subunit and, like the power supply in the frequency-shift converter, is designed with a link for adjusting the transformer to operate from 105/115/125 volts, 50 to 60 cycles, single phase.

The cable filter assembly of the comparator is nearly identical to the corresponding assembly of the frequency-shift converter. The individual filters in the comparator cable filter assembly are duplicates of those in the frequency-shift converter, filtering the a-c input, the teletype and tone outputs, and the external tone input circuits.

The blower subunit on the rear of the comparator is identical to the one on the frequency-shift converter.

The chassis-panel assembly of the comparator consists principally of the front panel and a skeleton chassis into which the two subunits are plugged and mounted. Its general construction is similar to that of the frequency-shift converter chassis-panel assembly. Cabled wires carry the comparator circuits in the chassis panel assembly between the subunit and cable-filter receptacles and to the electrical components on the front panel. The front panel components include the a-c power switch, the pilot light, and two monitor jacks. Other controls are described under "operation."

Operation

The operating controls of Frequency-Shift Converter CV-89A/URA-8A are illustrated in figure 10-8A, and those for Comparator CM-22A/URA-8A are illustrated in figure 10-8B. The associated monitor oscilloscope patterns are illustrated in figure 10-8C.

In order to obtain optimum performance of the converter-comparator group, it is necessary for the ET 3 to have a basic understanding of the receivers that are used with this equipment. The specific technical manual for the radio receivers being used should be available to the ET 3 to provide complete instructions.

When frequency-shift signals using narrow-shift operation are to be received, the BFO at the receiver should be adjusted to produce a beat note having an average center frequency of 1000 cycles (curve A, fig. 10-6). For wide-shift signals the BFO should be adjusted to produce a beat note having a center frequency of 2550 cycles (curve B, fig. 10-6). Where the BFO is not capable of producing this

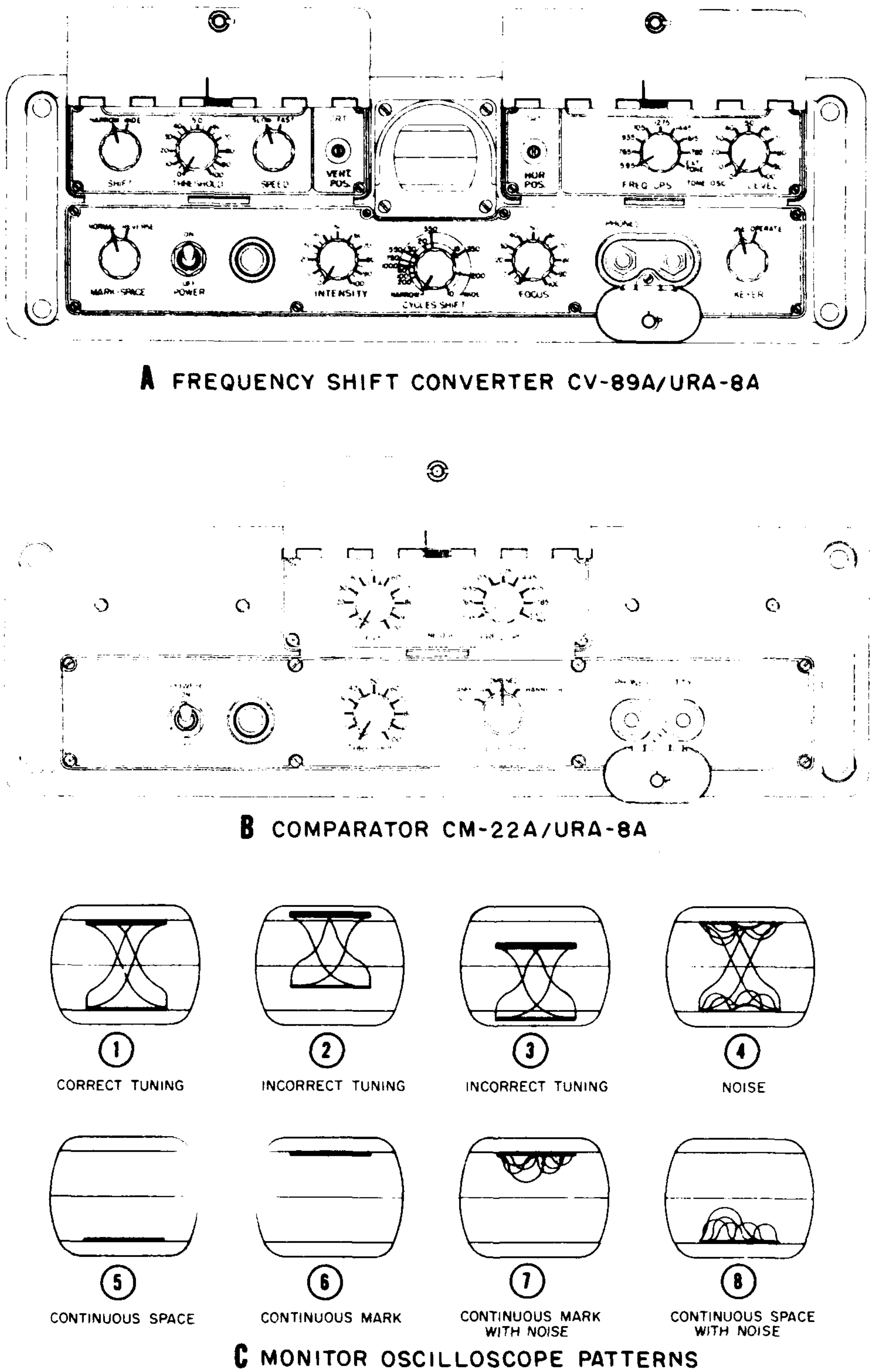

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Figure 10-8.—Operating controls and monitor oscilloscope patterns for converter-comparator group AN/URA-8B.

frequency, it may be obtained by slight detuning of the receiver, provided the selectivity is not too sharp.

When employing the higher frequency receivers (AN/SRR-12 and 13) on wide-shift signals, optimum operation is usually obtained with medium selectivity. However, under adverse noise and very weak signal conditions, improved operation can be obtained by using sharp selectivity, provided the BFO can be adjusted to be 2550 cycles higher or lower than the receiver intermediate frequency.

The operating controls for the frequency-shift converter include:

1. Threshold (adjusts bias (axis) to keyer grid).
2. Level (adjusts level of tone output).
3. Cycles shift (adjusts height of oscilloscope pattern and indicates cycles shift).
4. Vertical position (adjusts vertical position of oscilloscope pattern).
5. Horizontal position (adjusts horizontal position of oscilloscope pattern).
6. Intensity (adjusts brightness of oscilloscope pattern).
7. Focus (adjusts sharpness of oscilloscope trace lines).
8. Shift (adjusts discriminator circuits for narrow or wide-shift input).
9. Mark space (reverses polarity of discriminator output voltage).
10. Speed (selects fast- or slow-keying speed filters).
11. Frequency cps (selects frequency-determining elements for tone oscillator).
12. Keyer (for locking up, or closing of teletypewriter circuit during tuning of the receiver).
13. Power (switches a-c power input on and off).

The operating controls for the comparator include:

1. Threshold (adjusts bias (axis) to keyer grid).
2. Level (adjusts level of tone output).
3. Selector (selects input to comparator).
4. Frequency cps (selects frequency determining elements for tone oscillator).
5. Power (switches power on and off).

For diversity operation (fig. 10-8A&B):

1. Set the comparator selector control to TUNE.
2. Turn the comparator threshold control to ZERO.
3. Throw all power switches to ON and allow sufficient time for the receivers to stabilize.
4. Set the shift control on each converter to the WIDE position; or if the shift width of the signal is known, set the shift control to the corresponding position.
5. Turn the cycles shift on each converter to approximately 800 on the wide range. If the cycles shift of the signal to be received is known, set the cycles shift to the corresponding position on the narrow or wide range.
6. Adjust the other oscilloscope controls as required. These adjustments are summarized at the end of this discussion.
7. Set the speed control on each converter to the SLOW position for keying speeds of less than 60 words per minute or to the FAST position for keying speeds in excess of 60 words per minute. However, under unusual conditions, operation is sometimes improved by switching to the FAST position when receiving less than 60 words per minute.
8. Set the comparator frequency cps to the desired tone output frequency and turn the level control to the required output level when tone output is used.
9. Tune the receivers to their respective r-f carriers and adjust the tuning so as to center the signal pattern on the oscilloscope, as shown in figure 10-8 C (1). The tuning of the receivers affects the vertical position of the pattern. The cycles shift control on the converter adjusts the vertical size of the pattern. Aural reproduction of the audio output of the receiver is recommended to aid the operator to identify the signals. If the AN/SRR-12 or 13 receivers are being used, the add decibels switch should be set on +10 and the level control adjusted until the output meter reads 0 db. For this condition, the signal power is equal to 0 + 10 or 10 db. (Because zero db is equivalent to 6 mw into 600 ohms, 10 db is equivalent to a 60 mw output signal from the receiver.)

For dual diversity reception using two AN/SRR-12 or two AN/SRR-13 receivers, links are provided in the diode detector and AGC circuits that make these circuits common to the two receivers by means of receptacles, jacks, and suitable cabling. The gain of both receivers must be balanced. This action is accomplished by regulating the amount of amplification in the first two stages of the second i-f amplifier assembly of each receiver through adjustment of the diversity gain balance control. This

control is a recessed screwdriver adjustment on the front panel.

With a common AGC circuit for both receivers, r-f input signals to both receivers (local and remote) will affect both AGC circuits simultaneously. For example, if the r-f input signal to the local receiver becomes stronger than the r-f input signal to the companion receiver, the AGC bias in both receivers will increase. This action decreases the gain of the r-f and i-f stages of both receivers, thereby decreasing the relative magnitude of the output signal of the companion receiver with its relatively weaker input signal. This action facilitates the selector action in the comparator by emphasizing the difference in voltage between the two receiver output signals.

The oscilloscope on each frequency-shift converter functions as a monitor for tuning its associated receiver to the r-f carriers, as previously described. When the receiver is tuned correctly and the cycles shift is properly adjusted, the pattern on the oscilloscope of each converter should coincide with the upper horizontal line for a mark pulse and the lower horizontal line for a space pulse, as illustrated in figure 10-8 C (1). If the receiver is not correctly tuned, the oscilloscope patterns will resemble patterns (2) and (3) in the figure. Under bad noise conditions the patterns will resemble (4), (7), and (8). A correctly tuned steady space and steady mark signal is shown at (5) and (6) respectively.

10. The width of shift being received is indicated on the cycles shift wide or narrow scale when the oscilloscope mark space pattern is adjusted between the upper and lower calibrating lines, as shown at (1). The scale to read is the one that corresponds to the setting of the shift control located on the frequency shift converter (fig. 10-8A).

11. Set the comparator selector (fig. 10-8 B) to channel A (upper converter unit, fig. 10-4).

12. Turn the comparator threshold control clockwise until the teletype printer starts to print.

13. Try the channel A converter mark-space selector in both normal and reverse positions (fig. 10-8 A) and leave it in the position that gives correct copy on the teletype printer. In the correct position the characters are of the right polarity to control the teletype printer, but in the other position the characters are reversed and will not synchronize the control mechanism of the teletype printer. The latter condition results in no intelligence in the printed copy.

14. The teletype printer should now print correct copy (except in the low parts of a fading signal), indicating that A is ready for diversity operation.

15. Set the comparator selector to channel B (lower converter (fig. 10-4).

16. Turn the comparator threshold control clockwise until the teletype printer starts to print.

17. Try the channel B converter mark-space selector in both normal and reverse positions, as described for the channel A converter under item 13 (fig. 10-8A). Leave the selector in the correct position, as described in item 13.

18. The teletype printer should now print correct copy (except in the low parts of a fading signal), indicating that channel B is ready for diversity operation.

19. Set the comparator selector to COMBINED (fig. 10-8B).

20. Adjust the comparator threshold control to the highest scale reading that does not allow noise pulses to cause errors in the copy. A practical way to find this setting is to detune both receivers slightly off their respective r-f carriers to a position where noise alone is received. Then turn the threshold control clockwise to allow the noise to key the teletype printer. Finally turn the threshold control counterclockwise (back it off) to the position where the threshold bias is just enough to prevent the noise from keying the teletype printer.

21. Retune each receiver to its respective r-f carrier (as it was before detuning).

The frequency-shift converter-comparator group is now adjusted for diversity operation, either continuous or intermittent. Except for occasional retuning of the receivers and readjusting for changing conditions, the equipment should require little attention by the ET 3.

With experience in the use of this equipment the art of tuning and adjusting can be developed to the point where the proper settings can be readily recognized from the teletype printer copy and the monitor oscilloscope pattern. Under conditions of bad noise, it is frequently possible to obtain satisfactory teletype copy in diversity operation from signals that audibly are hardly distinguishable from the noise.

When placing the frequency-shift converter-comparator group into operation for the first time, it is necessary to make four initial

adjustments on the oscilloscopes associated with each of the converters. Two of these adjustments are semipermanent and need only be checked periodically after they are once set. The other two are panel controls that may have to be readjusted according to light conditions in the room in which the equipment is located.

To make these adjustments on the oscilloscope, (1) turn the receiver off and adjust the intensity and the focus on the converter (fig. 10-8A) to give a clear, fine trace on the screen with the desired brightness; (2) adjust the converter screwdriver adjustment marked VERT POS, to make the horizontal trace coincide with the horizontal centerline on the face of the oscilloscope; and (3) adjust the converter screwdriver adjustment marked, HOR POS, to center the horizontal trace on the screen.

After making these adjustments, turn the receiver on and proceed with the operation of the equipment. During operation the intensity and focus controls should be readjusted whenever necessary to give the clearest possible presentation.

CONVERTER-COMPARATOR GROUP AN/URA-17

Converter-Comparator Group AN/URA-17 (fig. 10-9) is a completely transistorized equipment designed to perform the same functions in the frequency-shift teletype receiving system as the AN/URA-8B, just described.

Although present procurement of frequency-shift converters is confined to the AN/URA-17, there are relatively few installations compared with the large number of AN/URA-8B converters. The greater quantity of AN/URA-8B converters will continue in service for several more years before eventual replacement by the newer model described briefly in the following paragraphs.

General Description

The AN/URA-17 consists of two identical converter units, one of which is shown in figure 10-10. Each converter has its own comparator circuitry. This achieves a considerable reduction in size from model AN/URA-8B, wherein the comparator occupied a separate chassis.

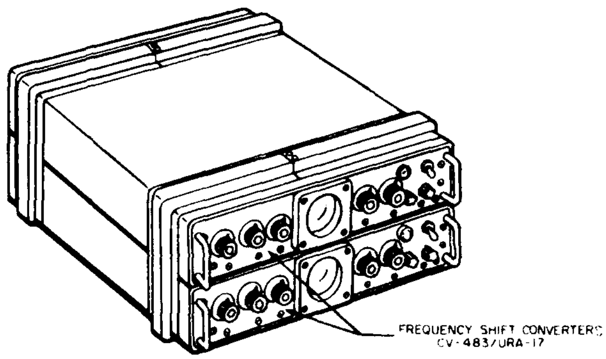

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Figure 10-9.—Converter-comparator group AN/URA-17.

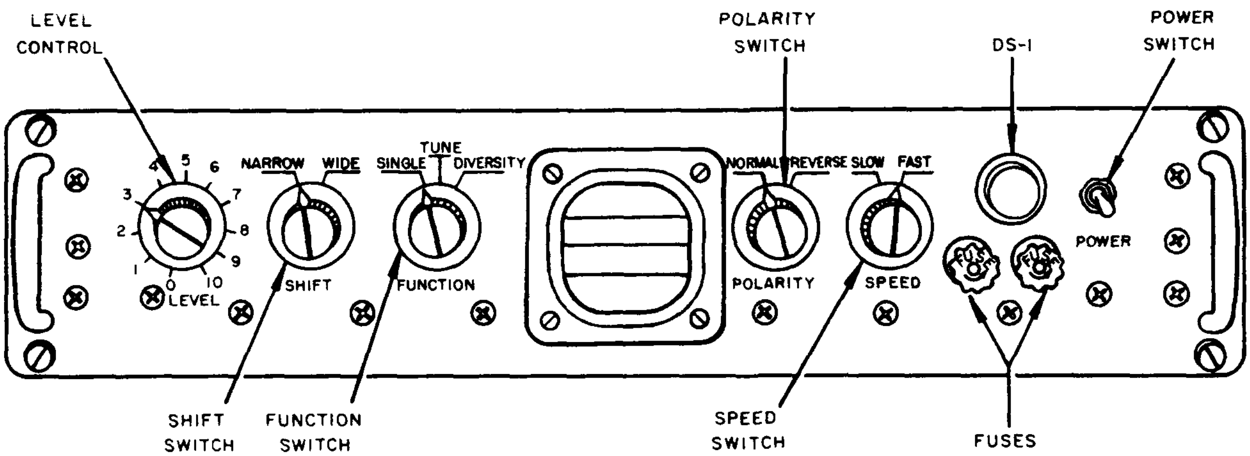

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Figure 10-10.—Frequency-shift converter CV-483/URA-17, front panel controls.

The physical size of the AN/URA-17 is further reduced through use of semiconductors and printed circuit boards. The complete equipment is less than half the size of the AN/URA-8B.

The converter-comparator can be operated with two radio receivers in either space-diversity or frequency-diversity receiving systems. When conditions do not require diversity operation, each converter can be used separately with a single receiver for reception of frequency shift teletype signals. In this latter usage, the two converters can be operated in two independent communication circuits.

For diversity operation, the function switch (fig. 10-10) on both converters must be placed in the diversity position. The teletypewriter may be connected to either converter.

The principal functions of the circuits of the complete equipment are represented in figure 10-11. Two receivers and a teletypewriter are also shown, connected for diversity operation. The two converters are identical, and one is shown as a single block for simplicity.

Tone Converter AN/SGC-1A

Another method of teletype communications employs tone modulation for short range (UHF and VHF) transmission, as mentioned in chapter 5 of this training course. Tone modulation employs a tone converter, one type of which is included in Radio Teletype Terminal Set AN/SGC-1A, as illustrated at the center of figure 10-12. Other associated equipment includes a

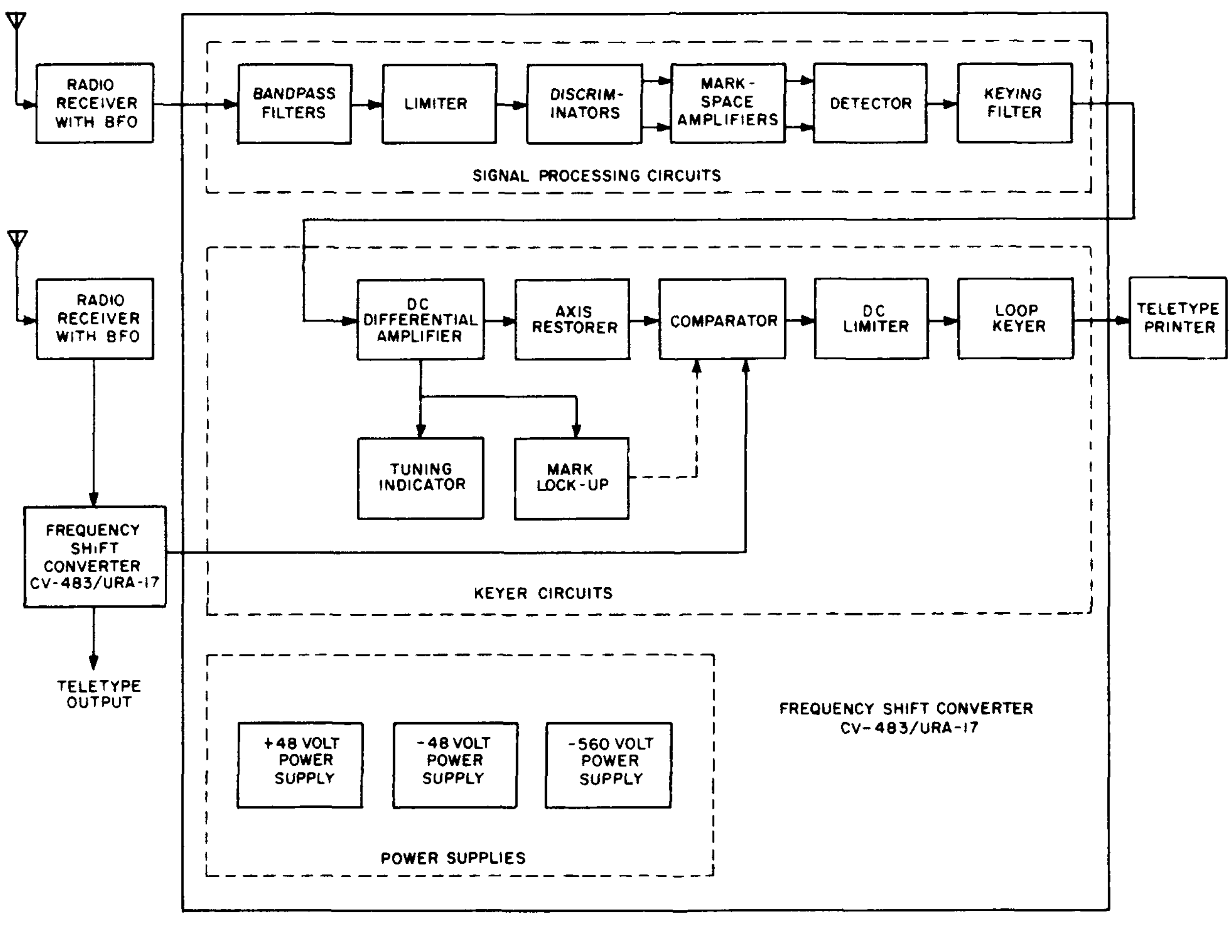

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Figure 10-11.—Converter-comparator group AN/URA-17, functional block diagram.

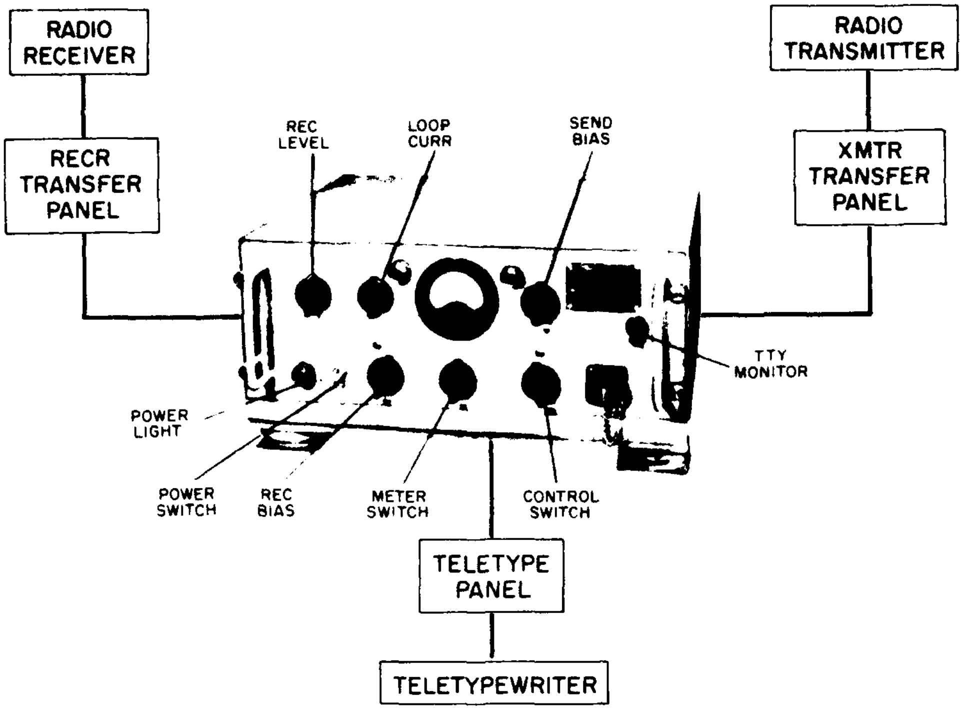

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Figure 10-12.—Teletype terminal equipment AN/SGC-1A.

radio receiver and transfer panel, a radiophone transmitter and transfer panel, and a teletypewriter and panel. The blocks indicate that any suitable standard Navy components may be used.

In tone modulation transmission, the teletypewriter pulses are converted into corresponding audio tones, which amplitude modulate the voice-frequency transmitter. Conversion of the audio tones is accomplished by an audio oscillator in the tone converter, which operates at 700 cycles when the teletype loop is in a closed-circuit (mark) condition and at 500 cycles when the loop is in an open-circuit (space) condition.

An internal relay in the tone converter closes a control line to the radio transmitter, which places the unit on the air when the operator begins typing a message. The control line remains closed until after the message has been transmitted.

When receiving messages, the tone converter accepts the mark and space tones coming in from an associated radio receiver and converts the intelligence of the tones into signals suitable to operate the make and break contacts of a relay connected in the local teletypewrter d-c loop circuit. This action causes the local teletypewriter to print in unison with the mark and space signals from the distant teletypewriter.

The receive level calibrated attenuator is located at the upper left side of the front panel on the tone converter. This control permits adjustment of the level of the incoming tone signals from the receiver. The loop current rheostat is next to the receive level control, and is adjusted to 60 ma when the teletype loop is in the mark, or closed circuit condition. A zero-center meter indicator is located at the upper middle portion of the front panel. An associated switch is located directly below the meter. It has several positions to permit measurements to be taken in all the necessary portions of the circuit.

Two indicator lights flank the upper part of the meter. One light indicates the receive condition and the other indicates the transmit condition. Both lights are off when the tone converter is in the standby condition.

The send bias rheostat is located at the right of the meter. This control permits correction

of any teletype distortion (for example, unequal length of mark and space signals) in the local teletypewriter loop when sending a teletype message.

At the far right is a jack marked, TTY monitor. A test or monitoring teletypewriter may be patched into this jack, thereby placing it in series with all other equipments in the loop. NOTE: headphones must not be plugged into this jack.

The power indicator light is located at the lower left side of the front panel of the tone converter. The power ON-OFF switch is located next to it.

The receive bias potentiometer is located at the right of the power switch. This control enables correction of distortion (unequal length of mark and space tones) in the receiving tone circuit.

The control switch is located at the right of the meter switch. The position of the control switch determines the function of the tone converter to either receive or to transmit teletype signals.

A 115-volt, 60-cycle convenience outlet is provided at the lower right of the front panel. It bypasses the power switch.

A block diagram of the tone converter is illustrated in figure 10-13. Typical oscilloscope patterns are included. The attenuator is located at the input of the receive circuit to permit adjustment of the level of the incoming 2-tone signal. The band-pass filter passes all frequencies in the band from 400 to 800 cycles and rejects all other frequencies. The amplifier limiter stages have a constant-output level. The frequency discriminator filter selects the fundamental frequencies of 500 cycles and 700 cycles and routes them via separate germanium rectifiers to corresponding d-c amplifiers (in the d-c amplifier block) and associated relay coils in the receiver relay block. A 700-cycle signal causes the receive relay to close the teletype d-c loop; a 500-cycle signal causes the relay to open the loop. Thus, corresponding mark and space signals are developed in the teletype loop circuit.

In sending, the mark and space signals in the d-c loop cause the send relay to apply either a d-c voltage or no d-c voltage respectively to the two-tone oscillator. A mark

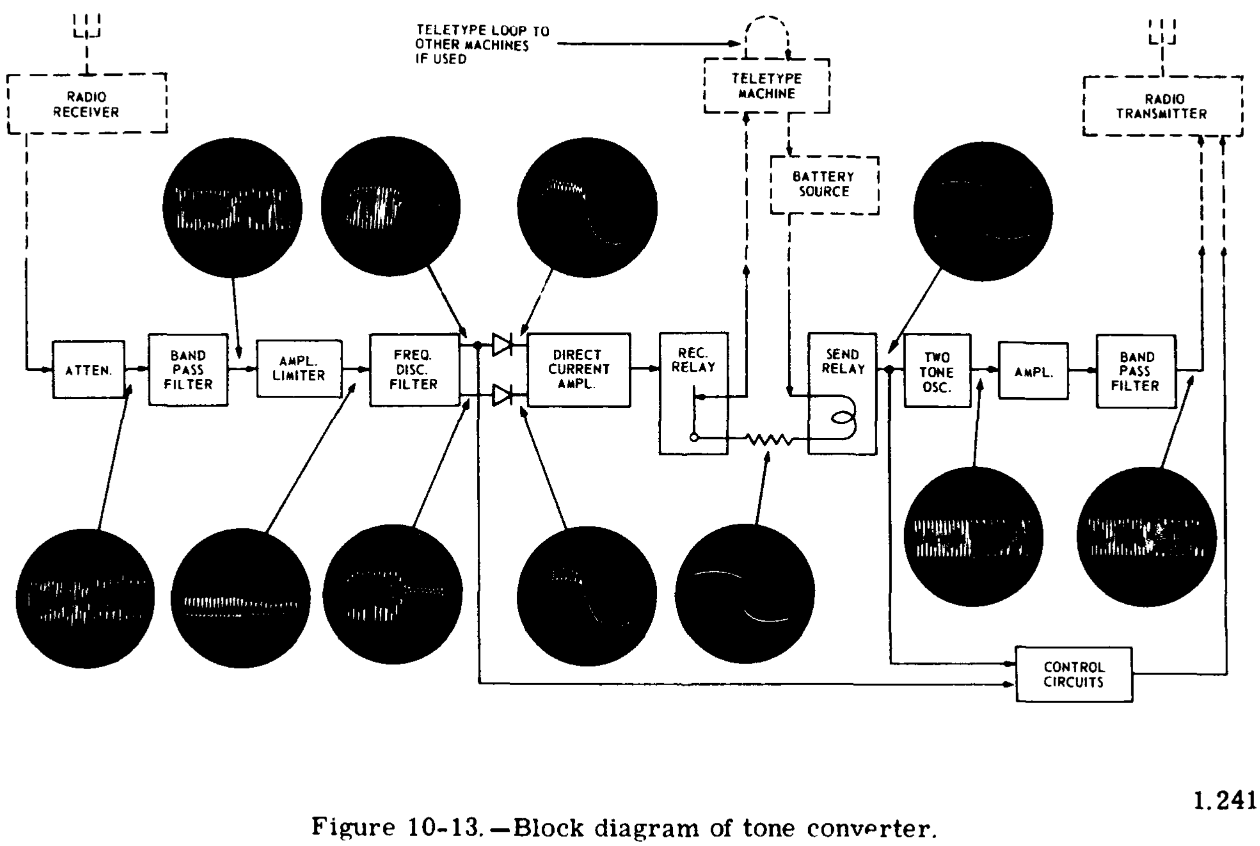

Figure 10-13.—Block diagram of tone converter.

signal causes the oscillator to operate at 700 cycles; a space signal causes it to operate at 500 cycles.

The output of the oscillator passes through a level-controlling potentiometer (not shown in the diagram) to the amplifier stage. The output of the amplifier passes through a band-pass filter to the ship's radio transmitter.

The control switch is used to change from one operating condition to another or to permit the accomplishment of specific operating or maintenance functions. If it is desired to prevent the sending of a message by the teletypewriter, the control switch may be turned to REC/STDY. Thus, the equipment cannot change to the transmit condition even though the teletypewriter is operated, but it can receive messages or remain in the standby condition.

In carrying on communications, the equipment should not be operated with the control switch turned to TRS because the equipment is then locked in the transmit condition and cannot receive any message until released by turning the control switch to one of the other two operating positions.

Usually, for half-duplex communication, this switch is set at the AUTO position. In auto condition, operators at two or more stations having this equipment can engage in full communication. After a station has completed sending its message, it is ready for reception of any return message after an automatic three-second time delay. When the switch is in the AUTO position, the tone converter may be in one of three conditions: receiving, transmitting, or standby. When in the standby condition, the reception of an incoming mark tone causes the control circuit to change to the receiving condition. Following the end of the incoming message, the internal circuits of the equipment shift back to the standby condition. When in this condition the operation of the local teletypewriter causes the circuits to change from standby to the transmit condition. After the last letter of the message is sent, there is a time delay of about three seconds and then the internal equipment circuits shift back to the standby condition. The interlocking functions prevent the equipment from shifting directly from transmit to receive, or vice versa. Thus, an incoming signal will not interrupt an output signal, nor will keying the local teletypewriter, when receiving, cause the circuit to shift to the transmit condition. The control circuits also, when shifted to transmit condition, cause the control contacts of the transmit control relay to the radio transmitter to close, thereby placing the transmitter carrier on the air.

After a station has sent its message, it is ready for reception of any return message following an automatic three-second time delay. Because of the small time delay inherent in the operation of the control circuits of the local and distant terminals the first character transmitted is usually lost. Therefore, the first character typed should be the "letters" key.

When placing the tone converter in operation, proceed as follows:

1. Turn the power switch (fig. 10-12) to ON.

2. Turn the control switch to TRS (transmit position). If the transmitter power has been turned on, the transmitter will send out a continuous tone; however, this does not matter for a few moments. If desired, the transmitter power may be left off until certain other adjustments have been performed.

3. Turn the meter switch to LOOP CURRENT. Adjust the control marked, LOOP CURR, until the meter reads 60 on the upper scale. If the meter reads zero, the source of loop current may not be energized.

4. Turn the control switch to AUTO. Then hold down the space bar on the teletypewriter and turn the meter switch to SEND BIAS. The meter should read zero on the upper scale. If it does not read zero, correct the reading to zero by means of the send bias control. Turn the meter switch to OFF <u>before</u> releasing the space bar.

5. The radio transmitter may be turned on if it was left off. When a teletypewriter message is received from a distant station, turn the meter switch to RECEIVE LEVEL and adjust the receive level control until the meter indicates 0 dbm (lower scale).

6. The last adjustment is the receive bias control adjustment for which an incoming teletypewriter signal is required from a distant station. The ET should request that a distant operator hold down his teletypewriter space bar for a minute. While he is holding down the space bar, turn the meter switch to RECEIVE BIAS and adjust the receive bias control until the meter reads zero on the upper scale. Then return the meter switch to the OFF position.

The equipment is now adjusted for operation with its associated teletypewriter, receiver,

and transmitter for communication with other stations similarly equipped.

COMMUNICATION PATCHING PANEL SB-1203/UG

Teletype panels and communication patching panels are used to interconnect the page printers and terminal equipments. Communication patching panel SB-1203/UG (fig. 10-14) contains 6 channels. The permanent and patching connections provide many circuit arrangements. Each channel comprises a circuit of 3 looping jacks (LPG), 1 SET jack, 1 MISC. jack, and a rheostat for adjusting line current. The LPG and MISC. jacks are identical, and are standard type phone jacks. The SET jacks incorporate the features of a double-pole double-throw switch, as will be seen later. The 6 line current rheostats provide individual channel current adjustment.

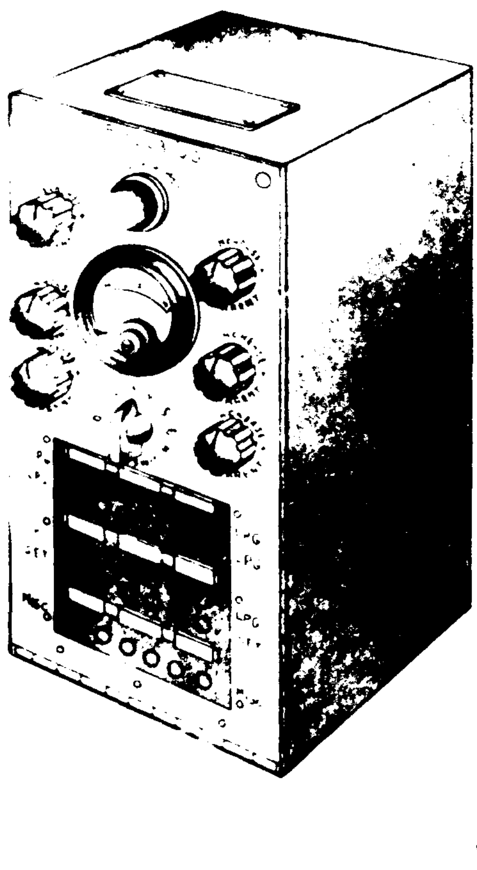

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Figure 10-14.—Communication patching panel SB-1203/UG.

The CURRENT METER is a d-c milliammeter. The METER SWITCH is a two-pole, seven-position, rotary selector switch. When the METER SWITCH is turned to any one of the 6 channels, line current in the selected channel will be indicated on the CURRENT METER.

Figure 10-15 shows a simplified schematic of a single channel. The other five channels are identical. Terminal equipment is connected to terminals 1 and 2 of terminal board TB-101, and the teletypewriter is connected to terminals 1 and 2 of TB-102. When line current is not supplied by the remote station loop, provisions are made to connect a local source of 115 volts d-c across terminals 1 and 2 of TB-104. These connections are paralleled across the corresponding terminals of each loop, and local current can be connected in or out of each loop by removable straps.

Resistor R119 limits the current in each loop to a maximum of 100 ma. Line current is adjusted by the 2500-ohm rheostat R108. One terminal of the rheostat is connected to the first looping jack J101. The SET jack J119 is connected to terminals 1 and 2 of TB-102 completing the circuit between the terminal equipment and the teletypewriter.

The teletypewriter may be transferred to any other channel by patching it from the SET jack J119 to one of the looping jacks in the channel desired. If it is desirable for the teletypewriter in this channel to be inoperative, a dummy plug is inserted in SET jack J119. An additional teletypewriter may be connected to the MISC. jack and patched into any channel.

Operating Adjustments

1. Turn all line current rheostats counterclockwise to allow minimum current.
2. Turn on local or remote power.
3. If the teletypewriter to be used is wired in the same looping channel as the terminal equipment to be used, no patching is required. If the teletypewriter is not wired in the same channel as the terminal equipment, insert one end of a patchcord in the proper SET jack and the other end in either of the looping jacks in the desired channel.
4. Turn the METER SWITCH to the desired channel and adjust the line current to 60 ma.

TRANSMITTER TELETYPE CONTROL UNIT C-1004A/SG

Another equipment used with teletype installations aboard ship is a control unit, for

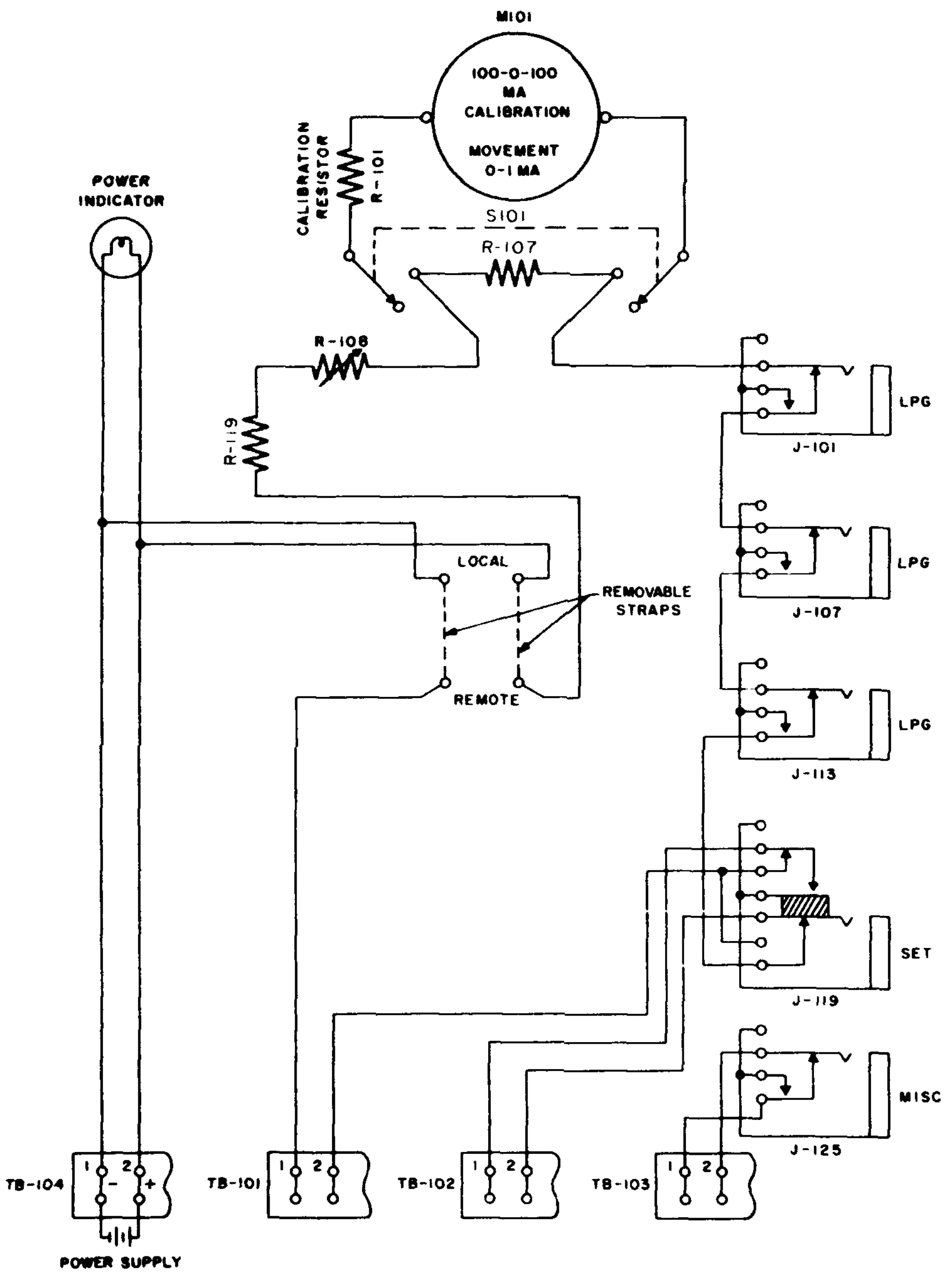

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Figure 10-15.—Communication patching panel SB-1203/UG, single channel simplified schematic diagram

example, Navy Model C-1004A/SG (fig. 10-16). This unit permits control of a teletypewriter radio circuit from a remote position. It provides a transmitter power ON-OFF switch, a power-on indicator lamp, a carrier-on indicator lamp, and a three-position rotary selector

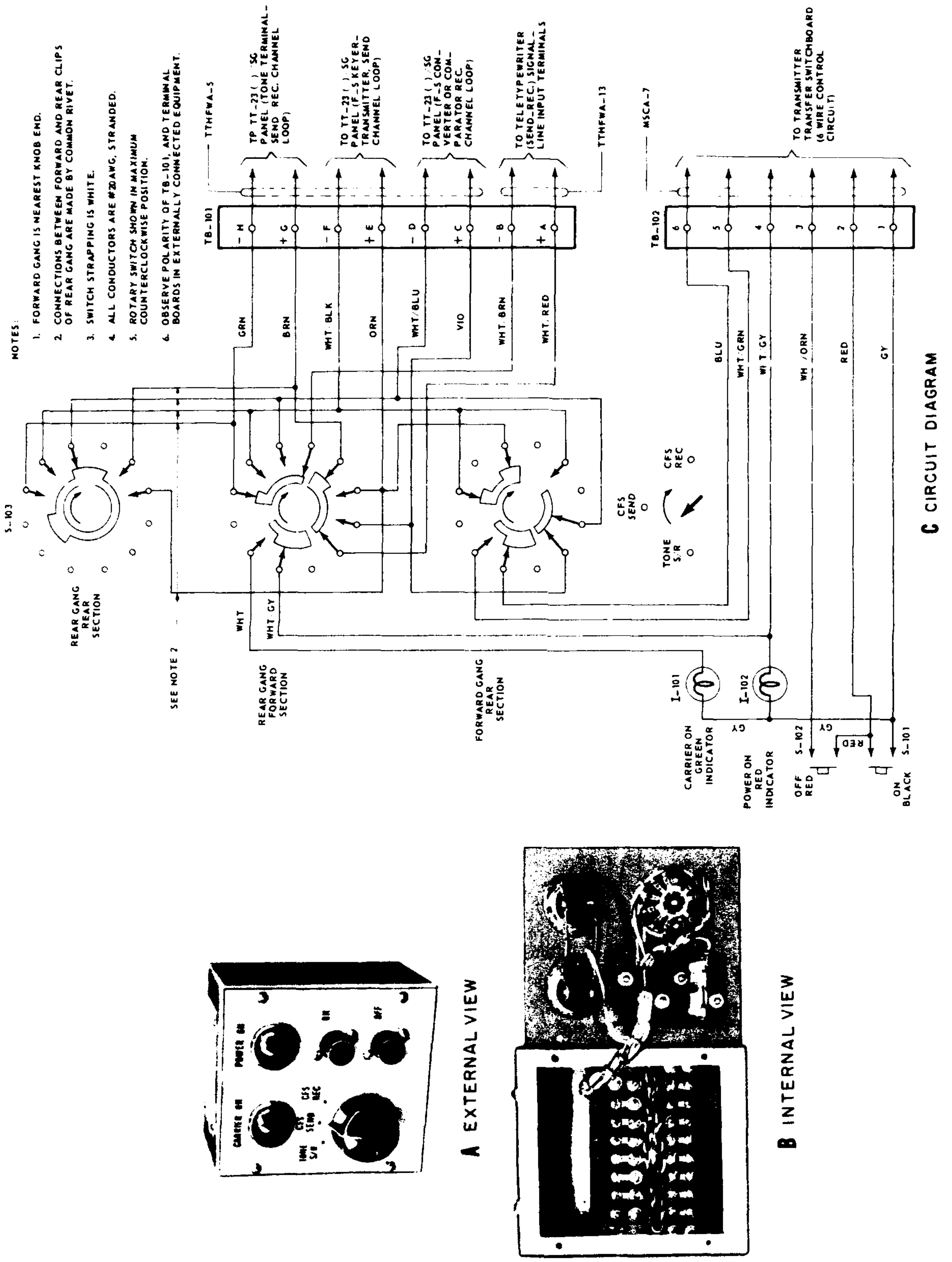

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Figure 10-16.—Transmitter teletype control unit C1004A/SG.

switch. The rotary selector switch, S103, provides the following functions:

1. Connects a send-receive teletypewriter to (A) a frequency-shift keyer circuit (CFS send), (B) a frequency-shift converter or comparator circuit (CFS receive) or, (C) a tone terminal on a send receive basis (tone S/R).

2. Shorts the other two unused sets of terminals when the send-receive teletypewriter is connected to the set of terminals associated with a particular switch position; that is, when the switch is in the TONE S/R position, the frequency-shift keyer terminals, E and F (CFS send) and the frequency-shift converter terminals, C and D (CFS receive) are shorted (close circuited).

3. Turns on the transmitter carrier by closing a circuit in the radio transmitter (terminals 5 and 6 are shorted in the CFS send position only).

4. Energizes the carrier-on indicator lamp in the CFS SEND position only.

When S103 (fig. 10-16C) is in the TONE S/R position, the carrier-on indicator lamp and the transmitter carrier are off; the teletypewriter is connected to the tone terminal loop (terminals G and H) while the unused terminals, frequency-shift keyer terminals E and F and frequency-shift converter terminals C and D, are shorted

When S103 is in the CFS RECEIVE position, the carrier-on indicator light and the transmitter carrier are off; the teletypewriter is connected to the frequency-shift converter circuit while the unused terminals, tone terminals G and H and frequency-shift keyer terminals E and F, are shorted.

FACSIMILE EQUIPMENT

Facsimile provides a means of reproducing still pictures over a communications system. The principle of operation is described briefly in chapter 5. Common operating adjustments on various components of facsimile transmitting and receiving terminal equipments are described below.

FACSIMILE TRANSCEIVER TT-41B/TXC-1B

Facsimile Transceiver TT-41B/TXC-1B is an electro-mechanical optical facsimile set of the revolving-drum type for the transmission and reception of page copy. It is used for transmission of maps, photographs, sketches, and printed or handwritten text over regular voice communications channels, either wire or radio, between two or more stations. Colored copy may be transmitted, but all reproduction is in black, white and intermediate shades of gray. Received copy is recorded either directly on chemically treated paper, or photgraphically in either negative or positive form. The equipment will transmit or receive a page of copy 12 by 18 inches in 20 minutes at regular speed or in 40 minutes with half-speed operation. A block diagram of the overall equipment is illustrated in figure 10-17.

The complete electrical circuit of the transceiver and power unit may be subdivided into the following eight principal components: (1) fork oscillator unit, (2) photo cell bridge modulator, (3) signal amplifier circuit, (4) phasing circuit, (5) motor circuit, (6) B+ regulator circuit, (7) rectifier power supply, and (8) exciter lamp supply.

The fork oscillator unit (V1, V2, and V3) generates a highly stable 1800-cycle audio signal for distribution to the bridge modulator circuit, the motor amplifier circuit, and the exciter lamp circuit.

The bridge modulator circuit, built around a 5652 photo tube, V24, is used only on transmission. It amplitude modulates the 1800-cycle signal in accordance with the variations in light intensity of the small portion of the transmitted copy being scanned at any instant.

The signal amplifier circuit (V10, V11, V12, V13, and V14) amplifies the 1800-cycle a-m signal. On transmission the circuit is fed by the photo tube bridge modulator; the output goes to the line terminal and thence via auxiliary equipment to the radio transmitter. On reception the circuit is fed by the signal on the line from a radio receiver; the output drives either the stylus for direct recording or the recorder lamp for photo recording. The signal amplifiers are also used in the talk-back circuit.

The phasing circuit, V15 and V16, is used for phasing of the facsimile receiver before each transmission. A series of phasing pulses from the transmitter actuates a clutch mechanism, which positions the receiver drum so that the clamp bars of both drums (receiver and transmitter) pass the scanning mechanisms at the same time. The clamp bars hold the copy to the drum (fig. 10-18).

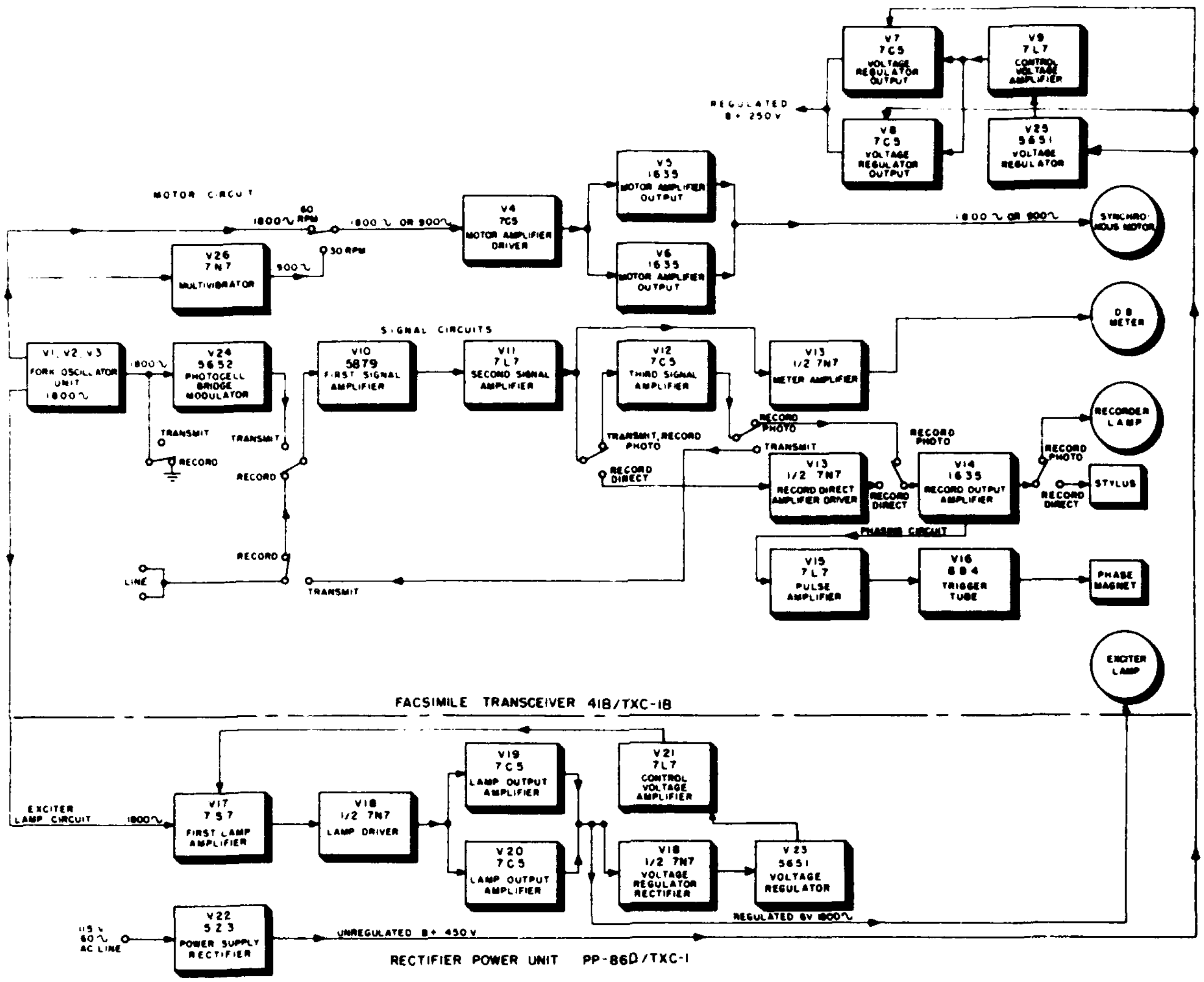

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Figure 10-17.—Block diagram of facsimile transceiver TT-41B/TXC-1B and rectifier power unit PP-86D/TXC.

The motor circuit (V4, V5, and V6, fig. 10-17) amplifies the 1800-cycle signal from the fork oscillator unit and drives the synchronous motor at constant speed. A multivibrator, V26, is used to provide half-speed operation of the synchronous motor.

The B+ regulator circuit (V7, V8, V9, and V25) provides a closely regulated voltage of 250 volts from the rectifier power supply of 450 volts. Regulated B+ voltage is used on critical transceiver circuits.

The rectifier power supply (V22 in the power unit) provides an unregulated 450-volt B+ output. The power unit also provides 6.3 volts a-c for filament operation and 115 volts a-c for starting the synchronous motor (not shown in the figure).

The exciter lamp supply (V17, V18, V19, V20, V21 and V23 in the power unit) amplifies and regulates the 1800-cycle signal from the fork oscillator unit to provide a constant amplitude, constant frequency signal for the transceiver exciter lamp, which illuminates the transmitted copy with a constant brilliancy.

All electrical operating controls of the facsimile transceiver, except the motor speed-control switch are located on the sloping front

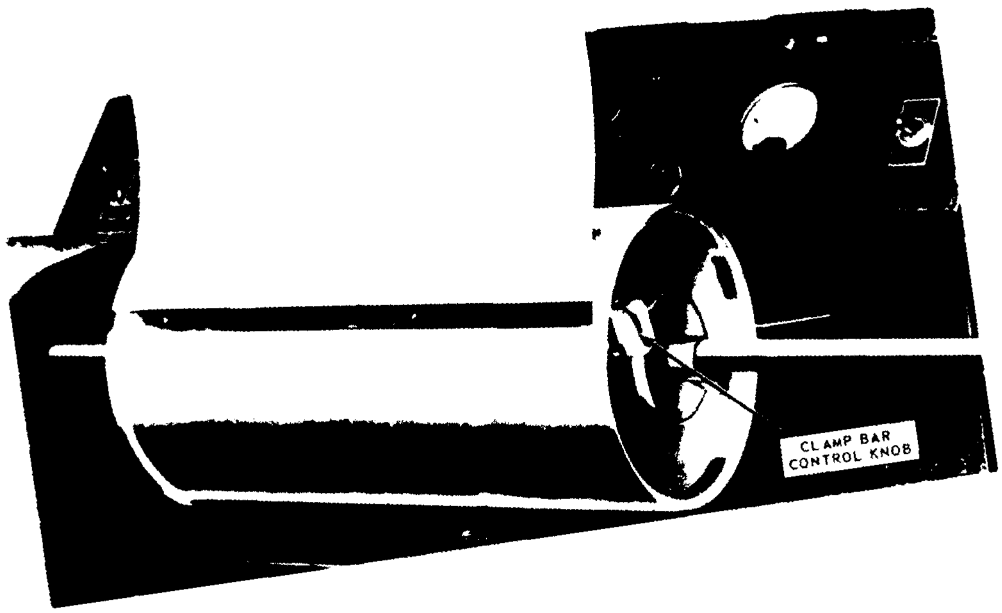

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Figure 10-18.—Placing copy on drum.

panel of the transceiver (fig. 10-19). The motor speed-control switch is located on the left end of the base of the transceiver. Two mechanical controls, the drum engaging lever and the clamp bar, are located on the drum. Input and output connections are located on the right-hand end of the transceiver. The power unit has no operating controls.

The power ON-OFF switch is located on the right-hand side of the control panel. It makes and breaks one side of the 115-volt, 60-cycle a-c line circuit feeding the primary of the main power transformer located in the rectifier power unit. In the OFF position power is removed from all parts of the facsimile set. In the ON position plate and filament voltages are applied to all tubes, and power is available for starting and operating the synchronous motor.

The selector switch located to the left of center on the front panel is the principal control for determining the function of the transceiver. It has five positions, which are labeled (from top to bottom) TRANSMIT, SET RANGE, STANDBY, RECORD PHOTO, and RECORD DIRECT.

In the TRANSMIT position the facsimile transmitting circuit is established, and impulses representing elements of the facsimile copy are sent out over the facsimile circuit. This is the normal operating position when the transceiver is transmitting copy. In this position the switch also closes the radio transmitter relay circuit associated with the carbon mike jack.

In the SET RANGE position the transmitting circuit is established as in the TRANSMIT position, except that impulses are not sent out over the line. This position is used when the operator is engaged in setting the contact range for transmitting a specific piece of copy.

In the STANDBY position the electron tubes are kept ready for operation of the transceiver. This is the normal setting during periods when copy is not being transmitted or received.

In the RECORD PHOTO position the receiving circuit is established to permit use of the recorder lamp for recording the received copy on photographic paper. This switch position is used to set the gain and to phase the receiving transceiver before recording either

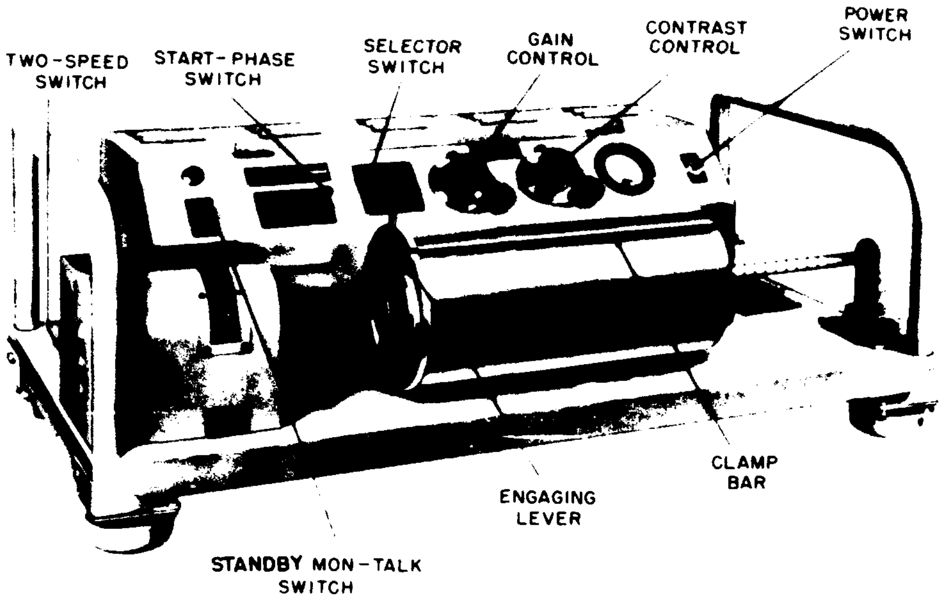

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Figure 10-19.—Facsimile transceiver controls.

"photo" or "direct." A raised stud on the selector switch nameplate enables the operator to set the switch at record PHOTO by "feel" in the dark room.

In the RECORD DIRECT position the receiving circuit is established to permit use of the stylus instead of the recording lamp. The stylus causes recording of received copy on electrosensitive recording paper. Moving the selector switch to the RECORD DIRECT position mechanically moves the stylus into contact with the paper.

The start-phase switch is a three-position, nonlocking lever type switch, which is spring loaded to return to neutral when released from either the START or PHASE positions. The switch is located on the front panel between the selector switch and spare fuse for the motor. The transmitting and receiving operators throw the start-phase switch to the START position momentarily to apply power to the start motor and to bring the synchronous motor above the normal operating speed. When the switch is released, the synchronous motor slows down to its normal operating speed and continues to operate at that speed. The receiving operator throws the start-phase switch to the PHASE position to energize the phasing circuit of the receiving transceiver while the transmitting operator is sending phasing pulses. When the relatively short-phasing operation is completed, the machines remain synchronized.

The motor speed control switch is a three-pole, double-throw toggle switch located on the left end of the base of the transceiver to the rear of the motor cover (fig. 10-19). It is used in the 60-rpm position for normal operation or in the 30-rpm position to provide half-speed operation. When transmitting over long radio circuits under adverse conditions, the 30 rpm half speed position can be used.

The standby-mon-talk switch is a three-position (two locking, one nonlocking) key switch located at the left on the front panel. The three positions, from the top to the bottom, are labeled STANDBY, MON, TALK. The talk-back circuit is operated only when the selector switch is on STANDBY.

In the STANDBY position, with a speaker plugged into the speaker jack, the speaker will be connected in the circuit and the operator can monitor the communication channel. If the standby mon-talk switch is in the STANDBY position, and the selector switch is also in the

STANDBY position, the synchronous motor will not operate. This position is used to receive voice communications when it is not necessary to have the motor running.

In the MON position, with a speaker plugged into the speaker jack, the speaker is also connected and the operator can monitor the communication channel. In this position, however, the motor receives power and can be started and run at synchronous speed. This is the normal position for receiving voice communications, when phasing transmitting and receiving equipments, preparatory to sending and receiving facsimile copy. Some 1800-cycle interference will be noticed in the talk-back circuit.

In the TALK position, with a speaker plugged into the speaker jack, the speaker becomes the microphone of a voice intercom system. The switch must be held in the TALK position; if pressure is released, it will snap back to the MON position. The TALK position is used when talking to the facsimile operator on the other end of the circuit.

It should be noted that the talk-back circuit only operates when the selector switch is at STANDBY. Voice communications cannot be carried on over this circuit when the selector switch is at TRANSMIT, SET RANGE, RECORD PHOTO, or RECORD DIRECT.

It should also be noted that the talk-back circuit will not function over a radio circuit that uses auxiliary radio equipnent unless the auxiliary equipment is bypassed for voice communi cations.

The contrast control is a calibrated potentiometer located to the left of the db meter on the front panel of the transceiver; it adjusts the contrast range (difference between minimum and maximum signal strength) of the transmitted signal by adjusting the magnitudes of the currents in the photo-tube bridge circuit. This control is operated only by the transmitting operator. The dial on this control is numbered from 1 to 100, with the applicable ranges for use when transmitting either positive or negative indicated on the dial.

The contrast control may be used to balance the bridge in the photo-cell bridge modulator (V24, fig. 10-17) either on maximum light (white) or on minimum light (black). In either case when the bridge is balanced, the output signal has a minimum amplitude. Thus, if the contrast control is adjusted so that the bridge is balanced when the light is a maximum, the output signal will have minimum amplitude on white and maximum amplitude on black. This type of transmission is called positive transmission. When the bridge is balanced on minimum light, the output signal will have minimum amplitude on black and maximum amplitude on white. This type of transmission is called negative transmission.

The gain control, located between the contrast control and the selector switch, is a dual potentiometer, which serves to control the level of the signal handled by the transceiver both in transmitting and receiving. It does not change the contrast range.

The front panel db meter, which serves as a guide in setting gain and contrast controls, is calibrated in db with reference to a zero-power level of 6 milliwatts in 600 ohms.

To turn the transceiver on, throw the power on-off switch to ON and turn the selector switch to SET RANGE. Normally a 5-minute warmup period should be allowed before making adjustments or actually transmitting.

To place copy on the drum, raise rear edge of clamp bar (fig. 10-15) by turning the clamp-bar control knob to its clockwise position. Place the lower edge of the copy (face up) under the rear edge of the clamp bar. Turn the knob to its counterclockwise position, thus closing the clamp on the leading edge of the copy and opening the other clamp. Revolve the drum forward, wrapping the copy around the drum. Insert the loose edge of the copy under the clamp; pull the copy tight around the drum with a wiping motion of the hand, and close the clamp by turning the clamp-bar control knob back to its center position. Examine the copy after it is placed on the drum to make sure there are no bulges.

The following adjustments should be made for transmitting positive for direct recording:

1. Turn selector switch to SET RANGE.
2. As a starting point, set the gain control at 65 and the contrast control near zero.
3. Turn the drum so that the whitest portion of the copy is illuminated by the spot of light. Carefully turn the contrast control to a higher setting until the meter reads the required minimum. Check the meter reading and move the drum slightly backward and forward while examining a different white portion of the copy to be sure that the whitest spot is used. For radio operation the required minimum will depend on the type of auxiliary equipment being used with the radio transmitter. Modulator, Radio MD-168/UX will accept any contrast signals from 10 db to 20 db, but the wire line minimum

(1/16 inch below the -10 calibration mark on the db meter) is recommended.

4. Move the drum so that the blackest portion of the copy is illuminated by the spot of light. Be sure that the blackest portion actually is used by again rotating the drum slightly backward and forward while checking the meter.

5. Adjust the gain control so that the meter reads +2 db.

6. Shift back to the whitest portion of the copy and readjust the contrast control for a minimum reading of -10 db on the meter.

7. Repeat steps 4, 5, and 6 until the final adjustments of the gain and contrast controls give meter readings, differing by at least 12 db between the blackest and whitest portions of the copy.

Adjustments for transmitting negative are not given here in the interest of brevity but may be obtained by referring to the appropriate technical manual.

The transmission of facsimile signals by amplitude modulation on the radio channel ordinarily results in a change in the loudness or levelness of the received signals with fading. If fading occurs, streaks or level changes will appear in the record picture. Therefore it is desirable to transmit a type of signal over radio circuits whose amplitude when demodulated at the receiving station will be independent of changes in the volume or level of the radio signal. This action may be accomplished by a frequency shift of the signal in which different picture values are represented by different frequencies. Because the facsimile transceiver generates an amplitude-modulated signal in transmitting and the recorder is designed to operate on an amplitude-modulated signal, picture signal conversion equipment is necessary between the facsimile transmitter and the radio transmitter, and between the radio receiver and the facsimile recorder.

The components of two radio facsimile transmission systems (introduced in chapter 5) will be described in the following portion of this training course. The first system employs carrier frequency-shift (CFS) keying and includes two auxiliary units between the facsimile transmitter and the radio transmitter. These units include Keyer Adapter KY-44A/FX and Frequency-Shift Keyer KY-75/SRT.

KEYER ADAPTER KY-44A/FX

Keyer Adapter KY-44A/FX (fig. 10-20) is used to provide d-c keying signals for frequency-shift exciter units in radio transmitters. The input is an amplitude-modulated, audio-frequency, facsimile signal that may be similar to the output from Facsimile Transceiver TT-41B/TXC-1B in the transmitting position. The input signal level should be maintained within a range of -20 to + 6 dbm. The output signal is a d-c voltage of varying amplitude between 0 and 20 volts d-c. The input carrier frequency range is from 1500 cycles to 7000 cycles, while the modulation sidebands can range from 100 to 7000 cps. There are four essential circuits: the input, the signal amplifier, the demodulator circuits, and the output circuits.

The power ON-OFF switch turns the set completely on or off. A preliminary warmup period of a few minutes should be allowed before using the set.

The test osc. level control is used for alignment of the unit. This control should be in the OFF position for normal operation.

The input-filter IN-OUT switch should be in the IN position only when receiving frequencies in the range of 900 to 2500 cycles and when signals are noisy. The switch should be in the OUT position for all other input frequencies.

The output selector switch determines the type of output from the unit. In the AMPLIFIER position the unit becomes a linear amplifier. In the DETECTOR position the unit becomes a detector with the carrier still unfiltered from the detected envelope. The output level meter reads average d-c values. The KEYER position converts the unit into a detector with the carrier removed to provide only the d-c keying signals.

FREQUENCY-SHIFT KEYER KY-75/SRT

Frequency-shift keyer KY-75/SRT was discussed previously with teletype equipment. The common operating adjustments for photo transmission are listed below.

Operating Adjustments

1. Turn the power switch (fig. 10-2) to ON. The white-jewel power lamp will light. The amber-jewel oven lamp will also light, thereby indicating that the crystal oven heater is on. This lamp will go on and off with changes in the crystal oven temperature. When the lamp is illuminated, heat is being applied and the lamp will remain on until the oven temperature rises to 70°C, at which time it will go off. When the

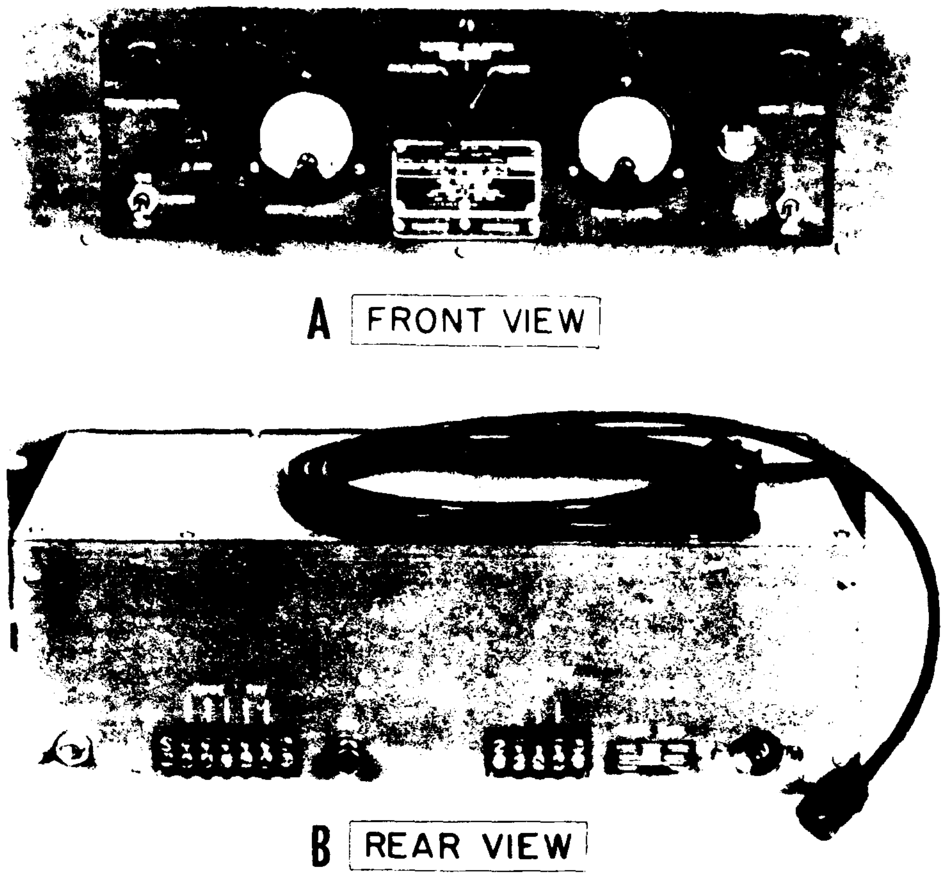

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Figure 10-20.—Keyer adapter KY-44A/FX.

lamp is off, no heat is being applied to the oven. The lamp will remain off until the oven temperature falls slightly below 70° C, at which time it will come on again.

2. After the oven lamp has turned off (the oven is at the correct operating temperature), set the plate switch at ON. The red-jewel plate lamp will light. The illumination given off by the foregoing three lamps may be adjusted by rotation of the serrated rim of the lamp assembly.

Note that when the keyer is not in use, the a-c power supply should remain connected and the power switch turned on to maintain the correct operating temperature of the oven. The plate switch should be set at OFF.

3. Set the test operate switch at PHOTO. In this position the limiting (V-101 and V-102, fig. 10-3) and waveshaping circuits are not used.

4. Set the crystal-oscillator switch at the position corresponding to the socket position of the crystal providing the desired channel frequency.

5. Set the frequency range switch to the desired output frequency of the keyer. This frequency is the sum of the crystal frequency and the 200-kc frequency from V-107.

6. Set the input filter switch at PHOTO.

7. Set the multipler switch at the position corresponding to the frequency multiplication factor employed in the transmitter. For example, if the multiplication factor is 8, the switch should be set at "X8."

8. Set the phase-modulation control at OFF (extreme counterclockwise position).

9. Set the metering switch at GRID.

10. Unlock the tuning control. Set the tuning control at a setting corresponding to the keyer output frequency and carefully adjust it about this setting for a maximum meter reading. A normal reading is about 1.5 ma (actual meter reading 0.5 ma). Lock the tuning control.

It will be noticed that three current peaks are observed on the panel meter. These peaks correspond to the resonant peaks for the lower sideband, the r-f carrier, and the upper sideband, respectively. The tuning control is normally set at the position that corresponds to the upper sideband resonant peak.

11. Set the metering switch at PLATE.

12. Release the lock on the output tuning control. Adjust the output tuning control for minimum plate current, as indicated on the meter.

13. Release the lock on the output level control. Set the output level control for the maximum grid drive required to drive the first amplifier or multiplier stage of the transmitter, as indicated by a maximum reading on the grid meter of the associated transmitter.

Care should be taken in this adjustment because if the tuning range is located near the lower markings on the tuning dial it is possible that a dip may also be obtained in the plate current near the higher markings of the dial due to the second harmonic of the keyer frequency.

14. Repeat steps 12 and 13, adjusting the output tuning control and the output level control simultaneously. As the output coupling is increased and the plate tuning maintained at resonance, the output power should increase, as indicated by a rising-plate current reading and an increase in grid drive, as noted on the grid meter of the associated transmitter. Rated power output is obtained when a reading of 85 ma (actual reading of the meter 0.425 ma) is indicated on the panel meter. Lock the output tuning and output level controls in position.

15. Set the deviation control at the desired deviation. This control functions to vary the amount of frequency deviation. The control dial has a multiplication factor of 100 for FSK operation and 200 for photo operation.

During high-frequency transmission when the r-f carrier frequency is multiplied by some factor in the transmitter, the amount of deviation of frequency shift is multiplied simultaneously by the same factor. Therefore it becomes necessary to reduce the amount of deviation in the frequency-shift keyer by a factor equal to the frequency multiplication factor of the transmitter. This action is accomplished by a multiplier switch that provides a means of dividing the frequency deviation by a factor of 1, 2, 3, 4, 6, 8, 9, or 12, thereby reducing the frequency deviation of the keyer signals by the same amount that these signals are multiplied in the transmitter. For example, if the frequency of the transmitter output is to be deviated 425 cycles when the transmitter frequency multiplication is 1; when the multiplication factor is 2, the frequency shift at the keyer output should be $\frac{425}{2} = 212.5$ cycles; when the transmitter multiplication factor is 4 the frequency shift of the factor keyer output should be $\frac{425}{4} = 106.25$ cycles.

In normal operation the deviation control is adjusted to obtain the desired deviation, as read directly on the calibrated dial of the control. After the multiplication factor employed in the transmitter is determined the multiplier switch is set at a position corresponding to this factor. In this manner the amount of deviation is determined and held constant despite any ensuing multiplication in the transmitter.

16. Set the metering switch at photo.

17. Adjust the photo input control, R102, for 5 volts, as indicated on the panel meter. The 5 volts can be obtained by locking the photo scanner in a maximum signal position. If the photo scanner is not available, any battery source providing 5 volts or more can be used.

18. To shut the keyer off, set the plate switch at OFF and the power switch at OFF.

The common operating adjustments of the auxiliary components of the FS method of radio facsimile transmission have been described in the preceding section.

A second method of radio facsimile transmission (introduced in chapter 5) is called the audio frequency-shift (AFS) method. This method may be used with UHF radiophone transmitters with only one additional piece of equipment between the facsimile transmitter and the radio transmitter. A typical equipment for this application is Modulator, Radio MD-168/UX.

MODULATOR, RADIO MD-168/UX

Modulator, Radio MD-168/UX (fig. 10-21) is designed to convert amplitude modulated facsimile signals from a facsimile transmitter

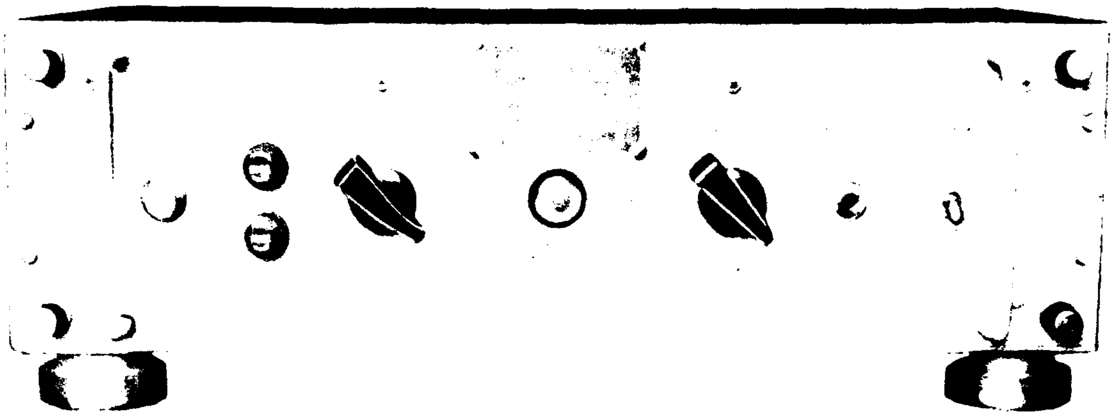

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Figure 10-21.—Modulator radio MD-168/UX.

(for example, Facsimile Transceiver TT-41B/TXC-1B acting as a transmitter) to audio frequency-shift facsimile signals of 1500 to 2300 cycles suitable for modulating a radiophone transmitter.

A block diagram of the modulator is illustrated in figure 10-22. Basically, the unit consists of a preamplifier; a keyer (detector); a variable-frequency, phase-shift oscillator; a frequency indicator; and a power supply (not shown). The amplifier increases the received facsimile signal to the proper level for operating the phase-shift oscillator and a pair of earphones. The input signal to the modulator may be monitored by using the phone jack. The frequency limits of the output signal may be monitored by means of a dual-type, tuning-eye indicator.

The input signal to the modulator has a frequency of 1800 cycles and an amplitude that varies in accordance with the light and dark segments of the picture being scanned at the facsimile transmitter.

The output signal from the modulator is an audio signal in which 1500 cycles represent the maximum signal input (in amplitude) and 2300 cycles represent the minimum signal input (in amplitude) to the modulator from the facsimile transmitter. Amplitudes between maximum and minimum signals are changed to corresponding frequencies between 1500 and 2300 cycles. The output from the modulator is connected to the audio modulator section of a radio a-m transmitter. Because the audio frequency-shift signal from the modulator is of constant amplitude the emitted radio frequency from the radio a-m transmitter is modulated at a constant percentage of modulation. The audio frequency-shift signal is sometimes referred to as sub-carrier-frequency modulation (SCFM).

The variable-frequency, phase-shift oscillator is caused to change its frequency in accordance with the variations in the magnitude of the d-c output voltage from the detector by means of a reactance modulator stage. The phase shift network is so connected that changes in the plate resistance of the reactance modulator (caused by the varying magnitude of the d-c voltage applied to its grid) cause a change in the time constant of one branch of the oscillator phase shift network. This action introduces a change in phase shift through the network, which in turn changes the frequency of the oscillator.

The operating controls and indicators are located on the front panel (fig. 10-21). The pilot lamp operates when the set is turned on. Both sides of the powerline are fused.

The adjust 2300 control is a potentiometer used to adjust the output frequency of the unit to 2300 cycles when the amplitude of the input facsimile signal is a minimum.

The adjust 1500 control is a potentiometer used to adjust the output frequency of the unit to 1500 cycles when the amplitude of the input facsimile signal is a maximum.

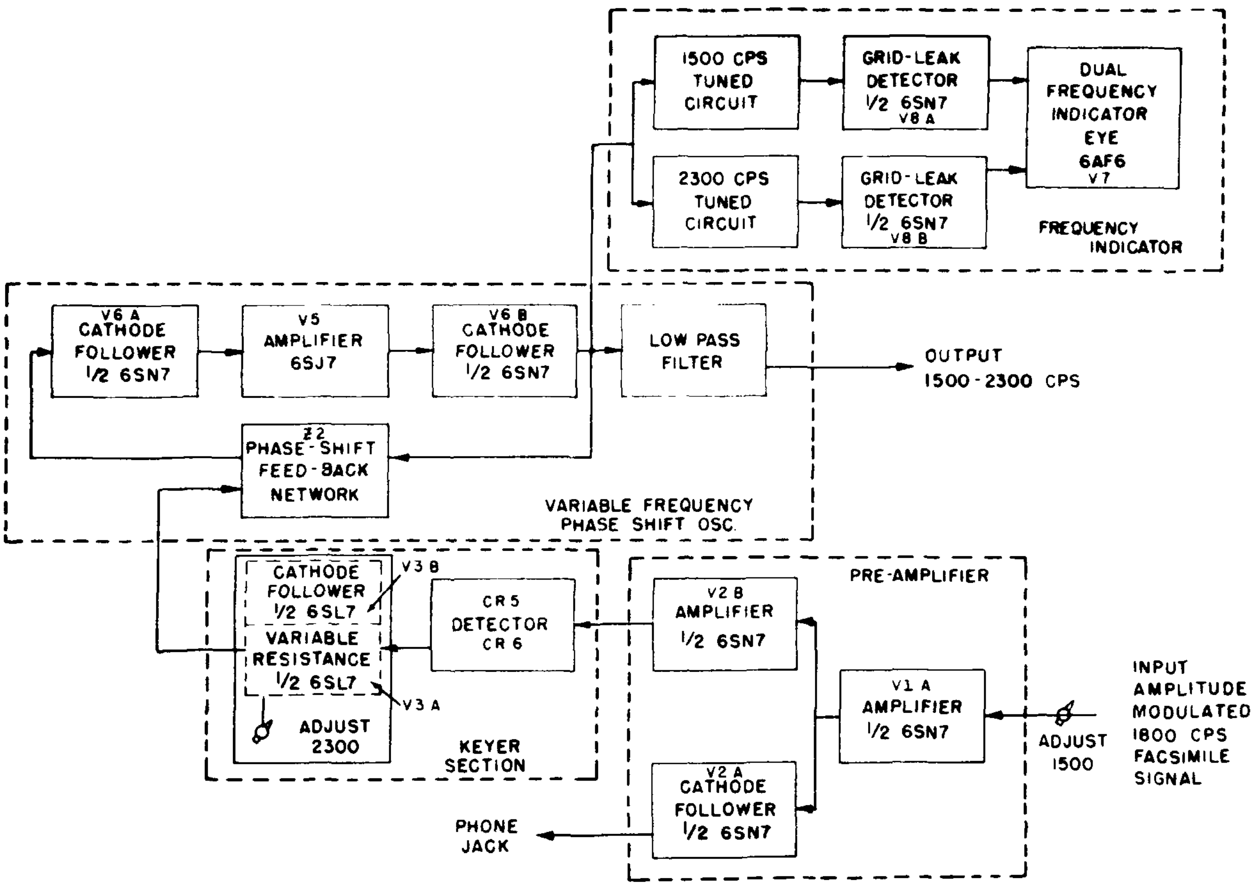

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Figure 10-22.—Block diagram of modulator radio MD-168/UX.

The 2300-1500 frequency indicator is used to indicate the proper frequency limits of the output audio frequency-shift signal. The left half of the indicator closes when the output signal has a frequency of 2300 cycles and the right half closes when the output signal has a frequency of 1500 cycles.

The gain of the amplifier is such that when the adjust 1500 control is set at the proper position, the audible level at the earphones will be a comfortable level.

When the power ON-OFF switch is in the OFF position, power is removed from the entire unit.

When operating the unit, throw the power switch on and allow a 5-minute warmup period.

Turn the adjust 1500 control to the extreme clockwise position. When an incoming signal is being received, the 2300-1500 tuning eye indicator will flicker; monitoring with the headphones will indicate when maximum and minimum levels are being received.

When the input signal to the modulator is maximum adjust the "adjust 1500" control until the 1500 side of the frequency indicator closes.

When the input signal to the modulator is minimum, adjust the "adjust 2300" control until the 2300 side of the frequency indicator closes.

Because the adjust 2300 and adjust 1500 controls are interdependent, repeat the preceding two adjustments.

FACSIMILE RECEIVING EQUIPMENT

To receive radio facsimile signals of either radio carrier frequency-shift transmission or

audio frequency-shift transmission, conventional superheterodyne receivers may be used. With either system, the signal output of the radio receiver is an audio frequency-shift signal in which 1500 cycles represent the maximum signal and 2300 cycles represent the minimum signal output from the facsimile transmitter at the sending terminal.

In order to convert the audio frequency-shifted signal output of the radio receiver into an amplitude-modulated signal suitable for operation of a facsimile recorder, an additional unit must be interposed between the receiver and the recorder. This unit may be Frequency Shift Converter CV-172A/U. The facsimile recorder may be similar to Facsimile Recorder RD-92A/UX. The frequency-shift converter is described first, and the subject of radio facsimile receiving equipment is concluded with a discussion of the common operating adjustments of Facsimile Recorder RD-92A/UX.

FREQUENCY SHIFT RECEPTION.—Frequency-shift reception (fig. 10-23 A) requires that a local oscillator frequency be introduced ahead of the second detector of the radio receiver in order to produce an audio beat note with the incoming frequency-shift radio signal. In general, the use of the receiver BFO does not give satisfactory results because for most receivers the converter and beat frequency oscillators do not have adequate stability. Usually one or the other will drift enough during transmission to cause the received copy to be useless toward the end of the transmission.

Frequency-shift reception with radio receivers that have crystal controlled converters and beat frequency oscillators is satisfactory because of the increased stability of the oscillators. The proper crystal frequency must be selected so that the converter oscillator places the FS signals in the center of the i-f pass band. The BFO crystal frequency is selected so that the audio output from the radio receiver is 1500 cycles for one r-f signal limit and 2300 cycles for the other r-f signal limit. A different crystal must be used in the converter oscillator for each operating frequency, but the BFO crystal is not changed. Usually a trimmer capacitor is provided in the converter oscillator circuit to permit a small frequency adjustment to be made.

For receivers that do not have crystal controlled oscillators, the use of a stable oscillator such as Navy Frequency Meter LM is recommended. The signal from the frequency meter auxiliary oscillator is fed to the radio receiver by placing a wire from the oscillator antenna binding post near the antenna terminal of the radio receiver. Positive or negative copy may be received, depending upon which side of the carrier frequency-shift signal the oscillator is set.

If the transmitting station uses the lower radio frequency limit for transmitting the maximum signal from the facsimile transmitter (fig. 10-23 B), the auxiliary oscillator should be set 1500 cycles below this frequency to reproduce the maximum signal at the output of the frequency-shift converter.

If the transmitting station uses the higher radio frequency limit for transmitting the maximum signal from the facsimile transmitter (fig. 10-23 C), the auxiliary oscillator should be set 1500 cycles above this frequency to reproduce the maximum signal at the output of the frequency-shift converter

If the radio receiver is equipped with an "S" meter, tune for maximum indication on the meter when the auxiliary oscillator is off and frequency-shift signals are being received.

The received copy defect may be blamed on poor radio transmission conditions; whereas, the defect may frequently be corrected by simply tuning the receiver properly. For optimum results care should be taken to tune the receiver so that the FS signals are centered in the pass band of the i-f amplifier in the radio receiver.

The same tuning procedures should be used for tuning a high stability radio receiver, as with a receiver employing an auxiliary oscillator. Turn off the BFO before making the tuning adjustments. After the proper tuning adjustments are made, as previously described, turn on the BFO and vary its control for the proper audio frequency output from the radio receiver. Do not change the receiver tuning to vary the audio frequency.

FREQUENCY-SHIFT CONVERTER CV-172A/U

Frequency-Shift Converter CV-172A/U (fig. 10-24) is used to convert 1500- to 2300-cycle facsimile signals received from a radio circuit to a-m signals suitable for operating a facsimile recorder (for example, Facsimile Recorder RD-92A/UX). The unit contains provision for

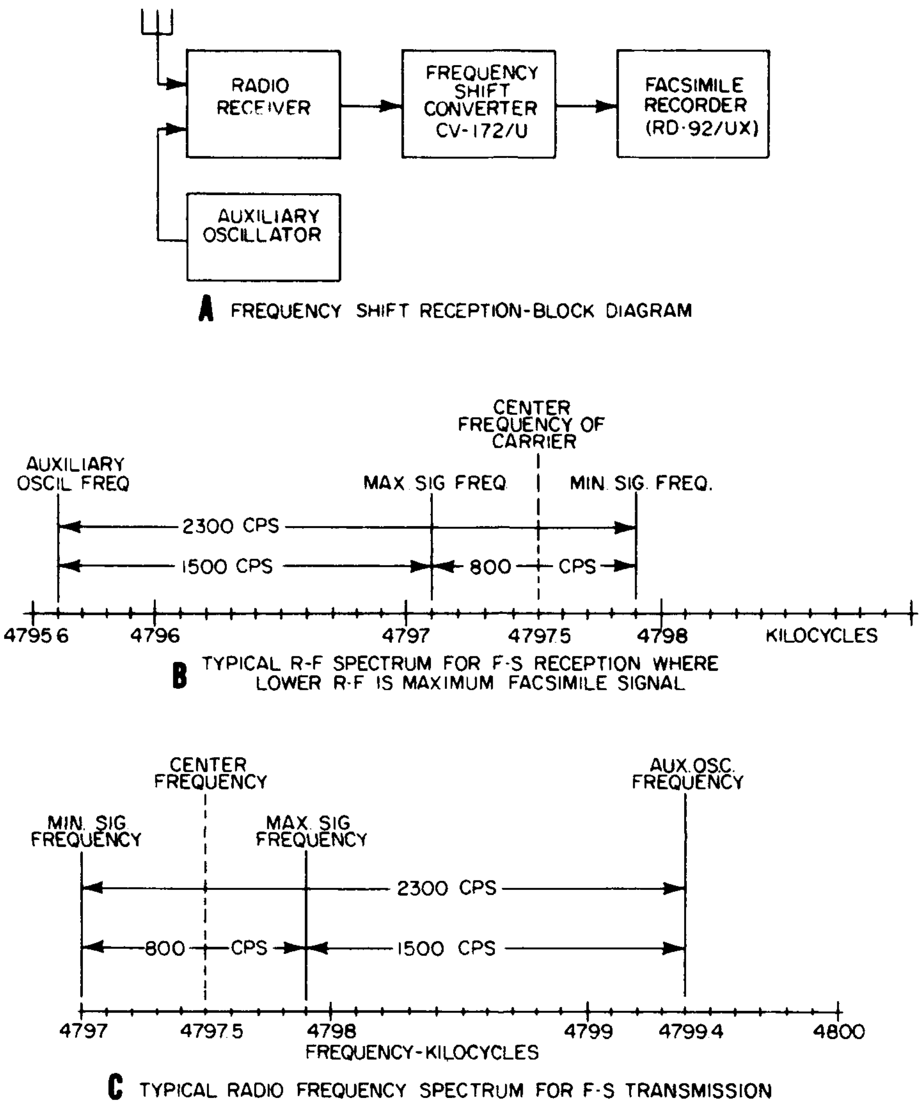

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Figure 10-23.—Radio facsimile FS reception.

audible monitoring of the incoming signal and for visual checking of the frequency limits.

Another method that may provide for even more reliable tuning is to turn off the auxiliary oscillator and tune slowly through the frequency-shift signals. As the signals are approached from one side a thumping sound will be heard. Continuing to rotate the tuning dial slowly in the same direction will cause this sound to disappear almost completely and then to reappear again before it disappears on the other side of the signal. The proper tuning position corresponds to the quiet zone between the two thumping sounds.

Satisfactory frequency-shift reception may be obtained with high stability radio receivers without the need for an auxiliary oscillator provided the receivers are properly tuned. If the converter and BFO have been sufficiently stabilized, the BFO can be used as the heterodyne oscillator to provide the audio frequency output.

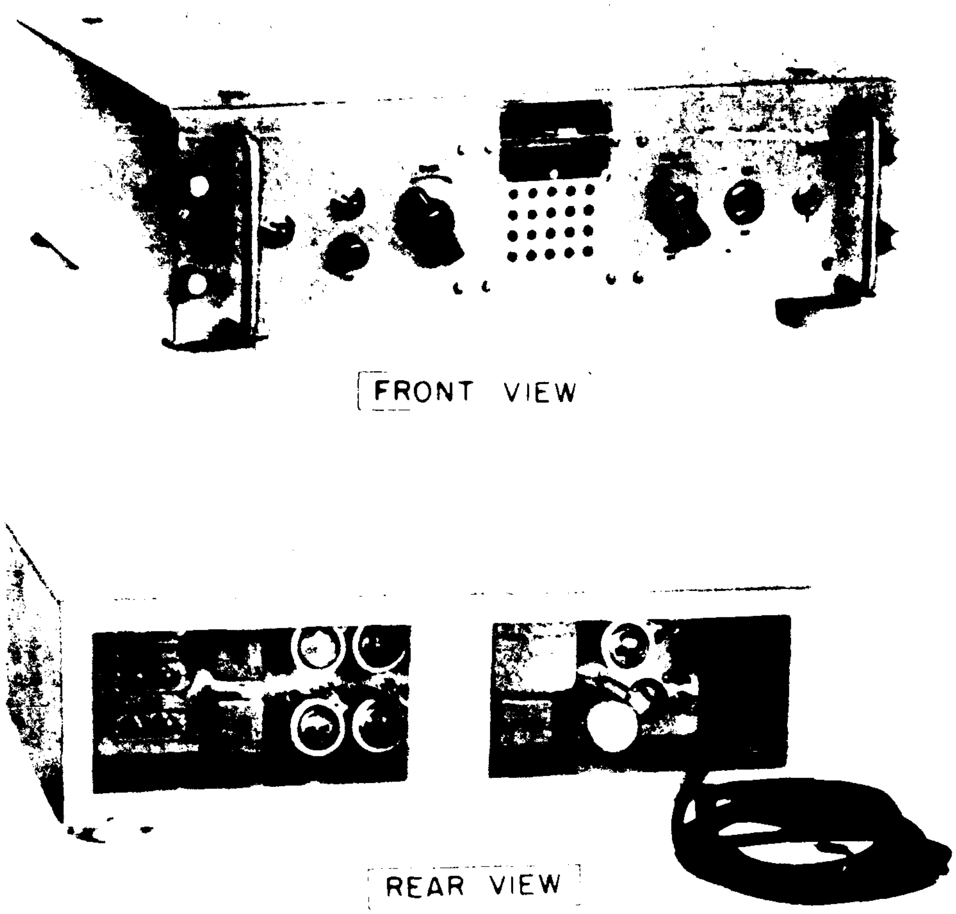

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Figure 10-24.—Frequency-shift converter CV-172A/U.

The ET 3 who is familiar with tuning c-w radio signals has observed that a-f or tone output from the radio receiver changes as either the main tuning dial or the BFO control is moved. Thus it is possible to have the right sense of signals (no inversion) and still not be tuned properly for optimum results. Improper tuning results in an inferior signal-to-noise ratio and may cause broadening of lines or multiple images somewhat similar to those caused by multipath transmission of the radio signals.

The facsimile signal obtained from the radio receiver is fed through an amplifier and filter to a limiter and then through a frequency discriminator (fig. 10-25). The output of the amplifier is controlled by an input level control potentiometer to adjust the signal level to the limiter. A loudspeaker with a separate volume control connects to the output of the line amplifier. This output also feeds two tuned circuits resonated at 1500 and 2300 cycles respectively to operate a tuning eye frequency indicator.

The input signal from the radio receiver is an audio frequency-shift signal in which 1500 cycles represent black and 2300 cycles represent white for the RD-92A/UX recorder. The discriminator is a low-pass filter having a cutoff frequency of 1500 cycles. The output from the filter at 2300 cycles can be adjusted to be from 10 to 20 db lower than the output at 1500 cycles. Thus, the input signal to the converter is changed from an a-f-s signal of substantially

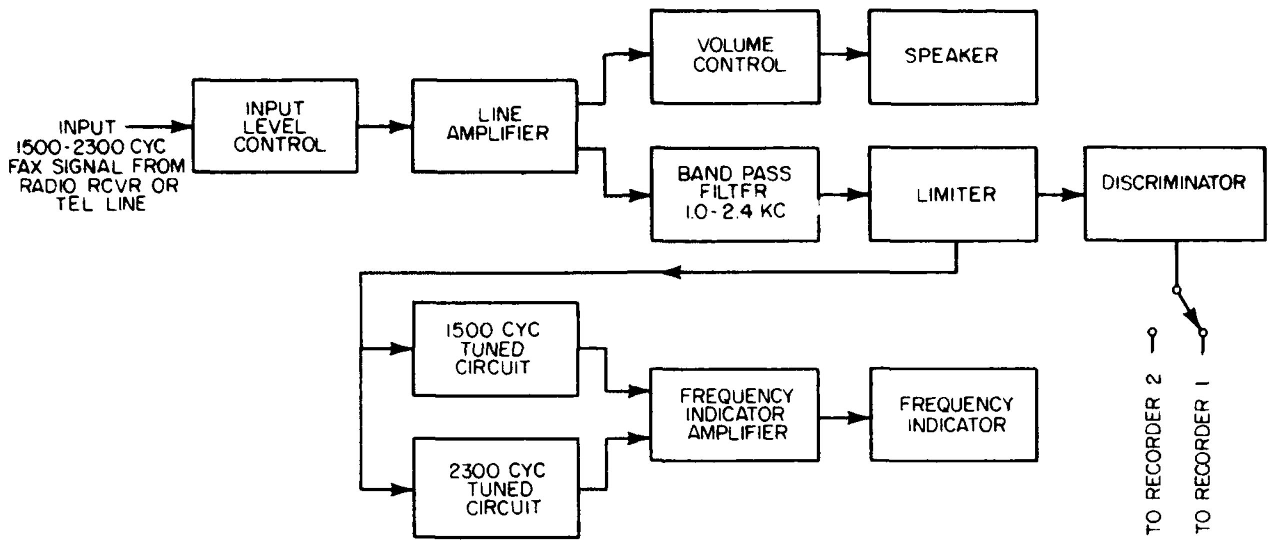

Figure 10-25.—Block diagram of frequency-shift converter CV-172A/U.

constant amplitude to an output signal of varying amplitude in which the maximum amplitude (corresponding to 1500 cycles) is 10 to 100 times the minimum amplitude (corresponding to 2300 cycles).

To operate the frequency-shift converter, turn the input level control clockwise (fig. 10-24). This action applies power to the unit. Allow a few minutes warmup time.

Adjust the input level and volume controls fully clockwise until a signal is received.

When a signal is received, adjust the input level control until the speaker does not distort. (Distortion exists when there are overtones.) This adjustment provides sufficient level to operate the limiter.

Adjust the volume control for a convenient speaker level.

When a 1500-cycle signal is being received, the "1500" tuning eye will close and the output will be the maximum signal level for, the facsimile recorder. Also, when a 2300-cycle signal is being received, the "2300" tuning eye will close. The difference in output levels will depend upon the trimmer control (not shown), which provides a variable-resistance bypass around the discriminator circuit.

When the radio receiving equipment is properly adjusted, the tuning eye indicators will show that 1500- and 2300-cycle signals are being fed to the input of the frequency-shift converter. When a copy that has mostly background is being received, the high stability radio receiver output may be adjusted by changing the BFO frequency to close the tuning eye corresponding most closely to the background signal frequencies.

FACSIMILE RECORDER RD-92A/UX

The output of Frequency-Shift Converter CV-172A/U may be fed to Facsimile Recorder RD-92A/UX (fig. 10-26) to make recordings of copy transmitted by Facsimile Transceiver TT-41B/TXC-1B (previously described) or equipment having the same transmission characteristics. The facsimile recorder is a self-contained unit comprising an amplifier-power supply chassis and four plug-in assemblies. The assemblies (fig. 10-27) are: (1) the audio frequency oscillator, (2) the amplifier detector, (3) the amplifier modulator, and (4) the recorder subassembly. A circuit test switch mounted on the front panel provides means for quickly testing all important circuits. Neon light indicators across individual fuses and tube heaters

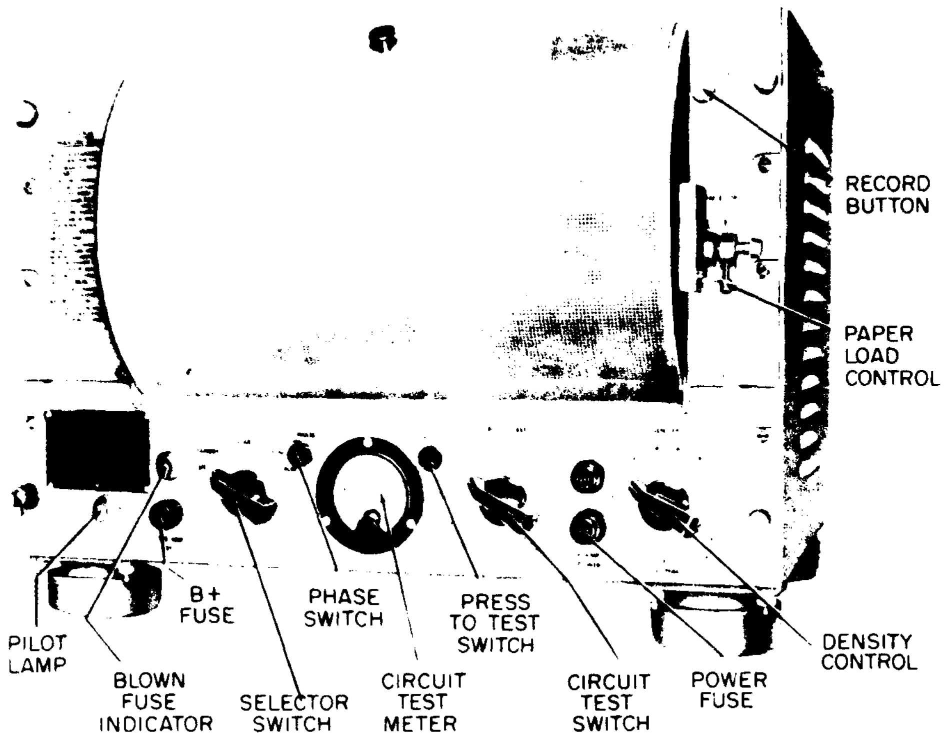

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Figure 10-26.—Facsimile recorder RD-92A/UX.

instantly indicate a blown fuse or burned out tube heater filament.

Facsimile Recorder RD-92A/UX performs its functions of recording pictures, drawings, or messages by rotating a drum at a constant speed, while feeding a stylus needle along the drum, one scanning line for each revolution until the complete drum has been covered. This function is performed by means of three motors and suitable gears and mechanical linkages contained within the recorder subassembly. The power, signal, and phasing currents for proper operation of the recording mechanism are obtained from the outputs of the electronic subassemblies.

The amplifier-detector unit (fig. 10-27) receives the input facsimile signal. This signal, consisting of phasing pulses and facsimile intelligence between the frequency limits of 900 and 2700 cycles, is amplified by a class A amplifier and demodulated through the action of a full-wave rectifier and low-pass filter to form a varying d-c facsimile signal.

The varying d-c facsimile signal output of the amplifier-detector unit is coupled to the amplifier modulator subassembly where it combines with a signal from a 15-kc oscillator in a modulator stage. The 15-kc output of the modulator varies with the amplitude of the d-c facsimile signal. The resulting modulated signal connects through the normally closed contact of relay K1 to the print driver and amplifier in the amplifier-power supply assembly.

The signal from the amplifier modulator unit is amplified by the print driver and amplifier to sufficient intensity, so that, when connected to the stylus needle in the recording mechanism assembly, it will record on the recording paper points representing varying shades of dark elements of the transmitted copy.

For phasing pulses, relay K1 is operated to transfer the signal from the amplifier modulator to the phasing detector and amplifier, located in the amplifier-modulator subassembly. The phasing pulses, which are transmitted at the beginning of each copy, are amplified to

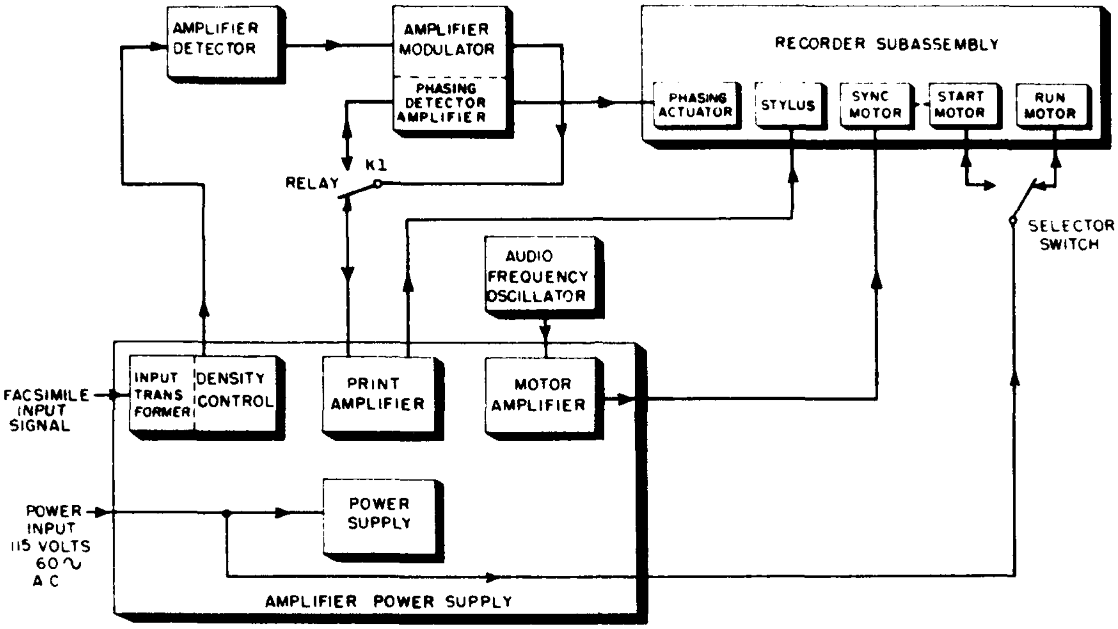

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Figure 10-27.—Simplified block diagram of facsimile recorder RD-92A/UX.

operate the phasing actuator in the recorder subassembly.

The phasing actuator, on receiving the phasing pulses, releases the stop bar on the synchronous-drive mechanism in the proper position to frame the recorder drum with the drum of the facsimile transmitter.

The a-f oscillator generates an 1800-cycle signal, which is amplified by the buffer amplifier (not shown) and motor amplifier in the amplifier-power supply assembly and then coupled to the recording mechanism assembly to operate the synchronous motor. The 1800-cycle signal also connects to the test signal position on the density control (fig. 10-27), where it is available for connection to the input of the signal amplifier for testing the various circuits with the circuit test switch.

The synchronous motor, rotating at a speed of 1800 rpm, is geared down to the required recorder drum speed of 60 rpm. A start motor, mechanically coupled to the synchronous motor, serves to bring the synchronous motor up to a speed higher than synchronous speed after which it coasts down to the synchronous speed when the synchronous motor runs on 1800-cycle power. The synchronous motor regulates the speed of the recorder drum. The run motor drives the drum through reduction gears.

When the record buton (fig. 10-26) is depressed and the selector switch is in the RUN position, the stylus needle records on recording paper fastened to the drum. The stylus is held in a carriage assembly that is moved across the drum to the right when engaged with a lead-screw shaft geared to the drum. When the carriage assembly reaches the right end of the recorder paper, it operates an automatic release mechanism, which disengages the carriage mechanism from the lead screw and lifts the stylus from the paper. A return spring, located in the left side gear box, then pulls the carriage back to the left side of the drum so that it will be ready for the next copy.

Operating Adjustments

To operate Facsimile Recorder RD-92A/UX (fig. 10-26) proceed as follows:

1. Turn the selector switch to the STANDBY position. Note that the pilot light lights up, indicating that power is being applied to the

recorder. Wait about 1 minute for the tubes to warm up. The recorder may be left at STANDBY while waiting for a transmission so that the set is ready for immediate operation.

2. Turn the selector switch to the START position. Wait about 5 seconds for the start motor to bring the synchronous motor above synchronous speed.

3. Turn the selector switch to the SYNC position. Wait until the synchronous motor coasts down, then locks in synchronous speed. This is distinguished by a distinctive high-pitch tone.

4. If the motor does not lock in but falls below the synchronous speed, switch back to the START position and repeat steps 2 and 3. If the motor does not come down to synchronous speed, turn to STANDBY and allow the motor to stop. Omit step 2 and switch directly to the SYNC position.

5. Turn the selector switch to the RUN position. It is necessary for the drum to rotate into the proper position for loading the paper.

To load paper on the drum, proceed as follows:

1. With the selector switch in the RUN position, push the paper load control to the left and hold there until the drum stops rotating. Then lift the projecting lever.

2. Open the hinged cover over the drum.

3. When the paper load lever is lifted, the paper clamp fingers on the drum will open. The paper load lever remains in the UP position. Drop a fresh sheet of recording paper into the space between the paper guide and the drum so that it rests up against the clamp fingers.

4. Flip down the paper load lever. This action causes the fingers to close quickly and grab the paper. This action also releases the drum, which quickly picks up speed to the synchronous speed of 60 rpm.

5. Close the hinged cover.

The adjust density control affects the gain of the signal amplifier so that the proper d-c voltage is obtained to key the print oscillator circuit. Incorrect setting of the density control may result in faulty recording. Proceed as follows:

1. Set the density control when facsimile signals are being received. When steady signals of maximum signal level are received, preferably on phasing signal, start near zero and advance the control to the lowest point that gives maximum reading on the meter on the front panel. This reading is normally about 100.

2. In some types of copy it is desirable to advance the dial setting of the density control slightly beyond the point that gives a maximum meter reading. Try this procedure if the copy is too light.

3. Leave the density control at the setting that gives the best recording.

The phasing operation is performed with the recorder drum stationary. Phasing pulses may be identified by a downward dip of the meter pointer occurring once a second. To phase the recorder proceed as follows:

1. Switch to the SYNC position and wait for the drum to stop.

2. Turn the phase button to LOCAL.

3. When phasing pulses are received, depress the phase button and hold depressed for five pulses. While phasing, two clicks per second are usually heard; one when the phasing actuator trips, and another when the stop bar passes the drum drive coupler. Press and hold for 5 meter pulses.

4. Turn the selector switch to the RUN position. The drum will rotate in the properly phased position.

5. Press record button when the copy starts. This is indicated by a change in meter pulses. Usually the meter reading drops down to about zero and flicks upward instead of downward. The stylus now feeds across the drum to print the copy, and releases automatically at the end of travel.

If it is desired to take less than a complete copy, release the stylus by (1) turning the selector switch from the RUN to SYNC position, or (2) operating the paper load lever. The stylus returns automatically to the lefthand end of the drum when it is released.

FACSIMILE RECORDER SET AN/UXH-2

Facsimile Recorder Set AN/UXH-2 (fig. 10-28) is a continuous page recorder designed to make direct recordings transmitted over land wires or radio. The set is designed to operate at 60, 90, or 120 scans per minute. When receiving from a transmitter with the proper signals, the unit will automatically phase, start recording at the beginning of a transmission, stop when the transmission is complete, and compensate for changes in signal level during the recording. When this automatic operation is utilized the set may be left unattended.

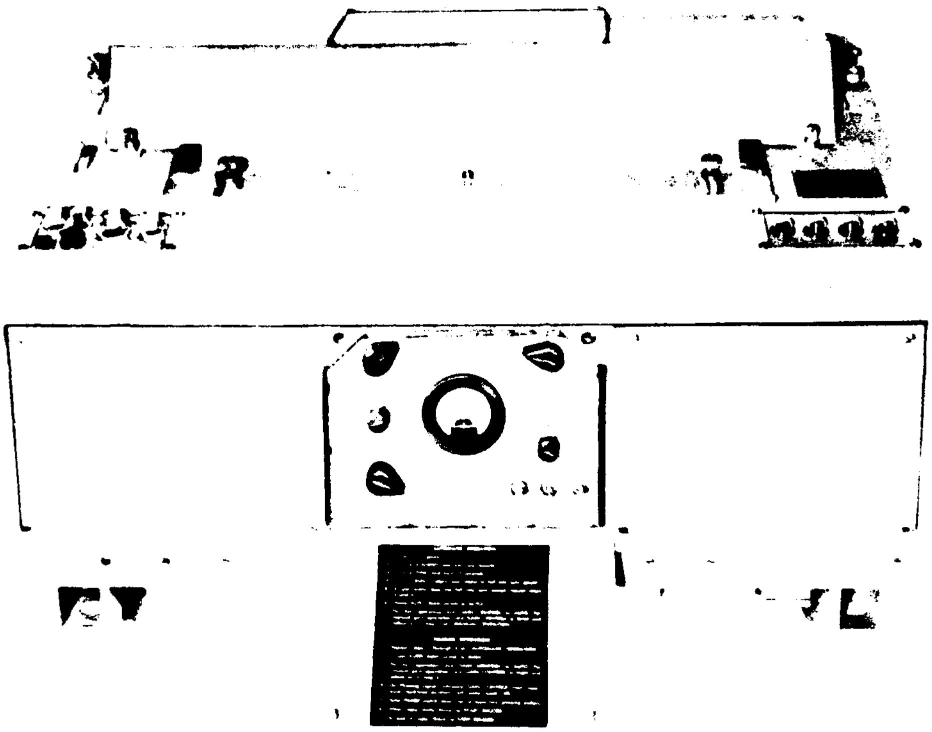

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Figure 10-28.—Facsimile recorder set AN/UXH-2.

Manual operation may be utilized when the transmitting station is not equipped to transmit the necessary control signals for automatic operation.

The AN/UXH-2 consists of three major assemblies: (1) Recorder RO-76/UXH-2, (2) Power Supply PP-1901/UXH-2, and (3) Electrical Control Amplifier AM-1845/UXH-2.

Recorder RO-76/UXH-2

The recording mechanism consists of the SYNC system, run system, stylus and base assembly, and paper feed system. The synchronous (SYNC) motor (fig. 10-29) is brought up to speed by a split-phase induction start motor (not shown). The SYNC motor is then supplied with power by a fork-controlled oscillator circuit, and operates at a synchronous speed of 600, 900, or 1200 rpm, depending upon the scans per minute to be recorded.

The SYNC shaft is driven by the SYNC motor through a reduction gear train, a flywheel and ratchet assembly, and SYNC clutch assembly (fig. 10-29). When the recorder is in standby condition, the SYNC motor is running and the run motor, stylus band, and SYNC arm shaft are stationary.

The phase magnet armature is normally held back so as not to engage the clutch stop arm. During the phasing period the holding current to the phasing magnet is off. The released armature blocks the clutch stop arm, but the sync clutch ratchet continues to rotate at synchronous speed while the sync clutch pawl slips over the ratchet teeth. When a phase pulse is received, the phase magnet armature is pulled back momentarily to permit the clutch to resume rotating in phase at synchronous speed. Subsequent phase pulses will pull the phase magnet armature back each time the stop arm passes it.

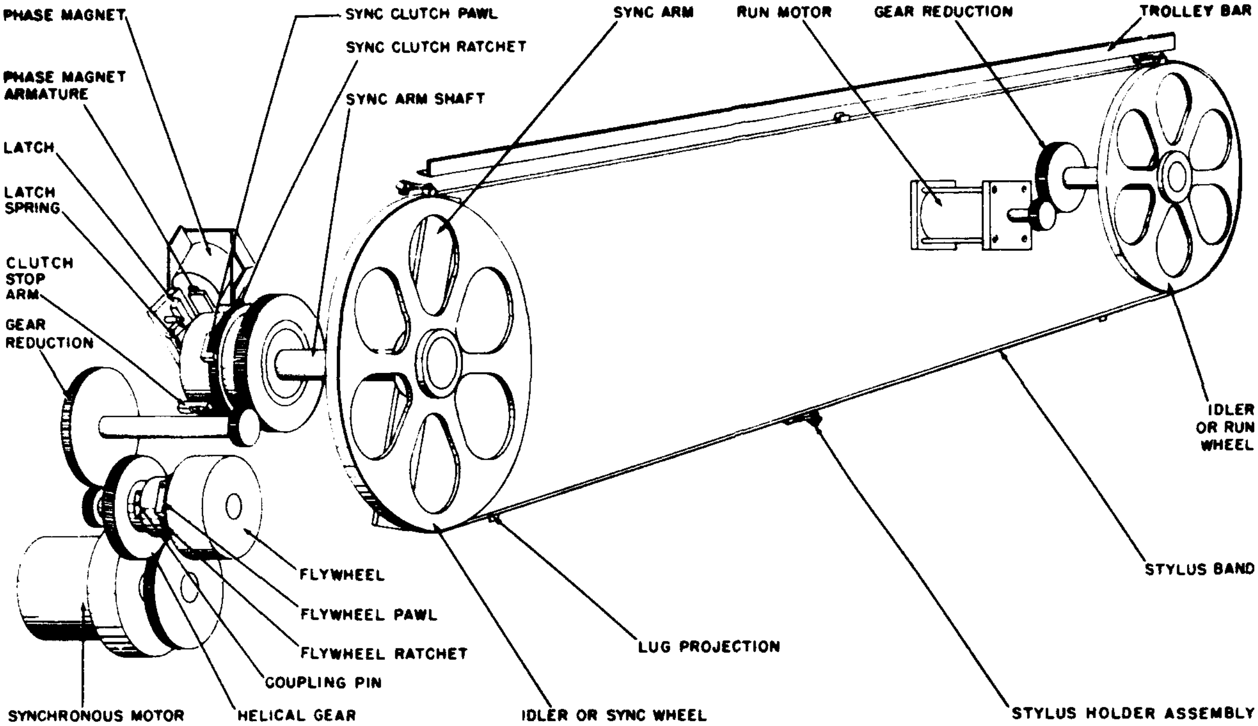

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Figure 10-29.—Recorder facsimile RO-76/UXH-2, simplified view of synchronous drive and run system.

When the start-record signal is received, the run motor starts and drives the stylus band through a reduction gear train and the run wheel.

Power Supply PP-1901/UXH-2

The Power Supply PP-1901/UXH-2, and associated voltage regulator circuits (fig. 10-30), furnishes 6.3 volts a-c, 400 volts d-c (HI B+), 225 volts d-c regulated B+ (RB+), and bias supplies for the set.

Normally the input voltage is 115 volts single phase a-c, however, connections are provided for operation on 220 volts a-c. A utility outlet J601 is provided on the input line to operate auxiliary equipment when desired. Power line filter FL 601 isolates the recorder set from other equipments connected to the power line.

Electrical Control Amplifier AM-1845/UXH-2

Electrical Control Amplifier AM-1845/UXH-2 consists of signal amplifier circuits, automatic level control and print amplifier circuits, automatic control circuits, fork oscillator and SYNC motor drive circuits, and speaker amplifier and test signal circuits.

SIGNAL AMPLIFIER, ALC, AND PRINT CIRCUITS.—The input facsimile signal from the secondary of T301 (fig. 10-30), is fed through gain control R301 to ALC amplifiers V1A and V1B. ALC lockout switch S306 is a single-pole double-throw switch and is part of gain control R301. If the gain control is set at the automatic position, the ALC feedback network controls the bias on V1A and B, automatically compensating for variations in the level of the facsimile signal. Setting the control

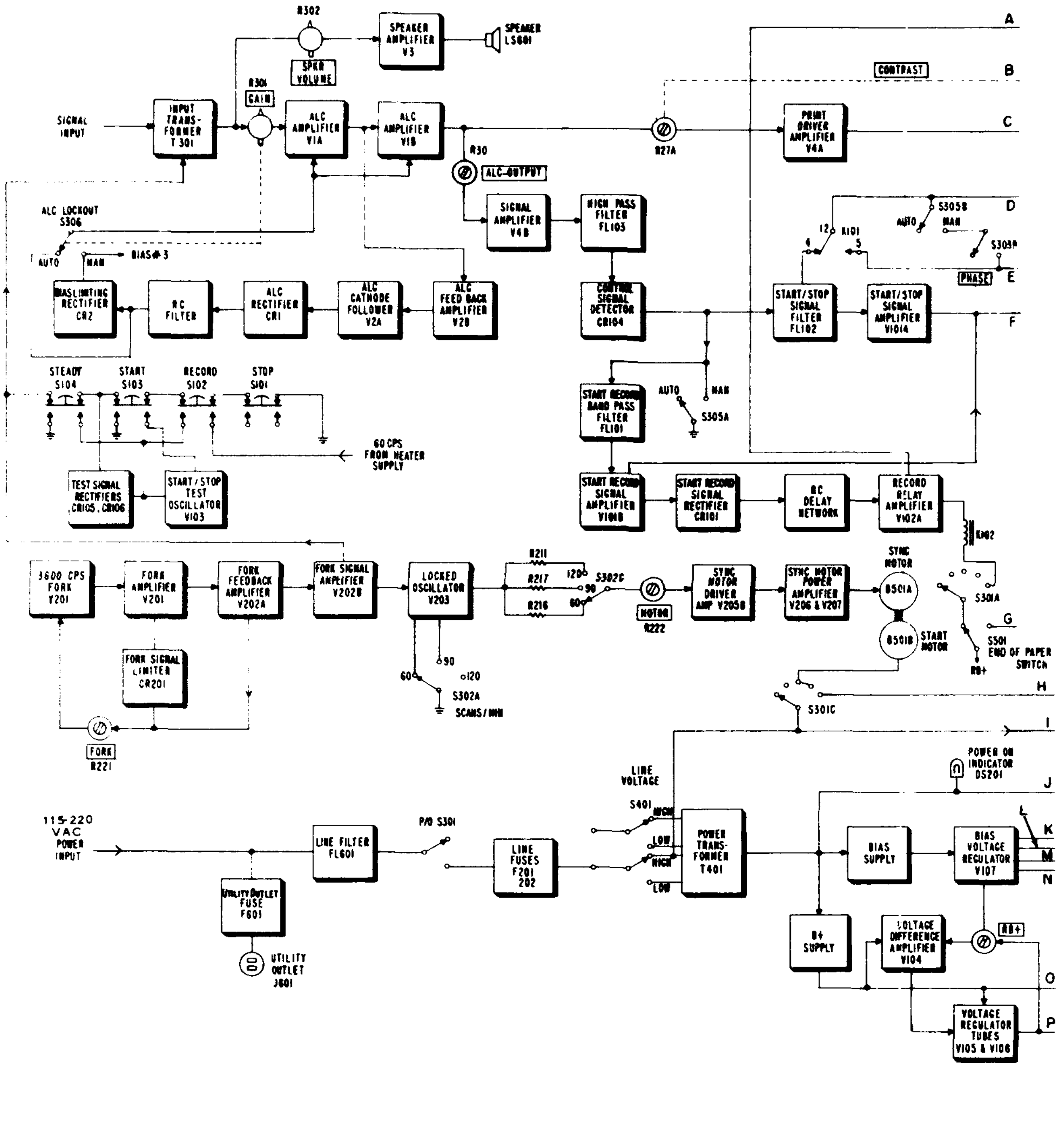

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Figure 10-30.—Facsimile recorder set AN/UXH-2, overall block diagram.

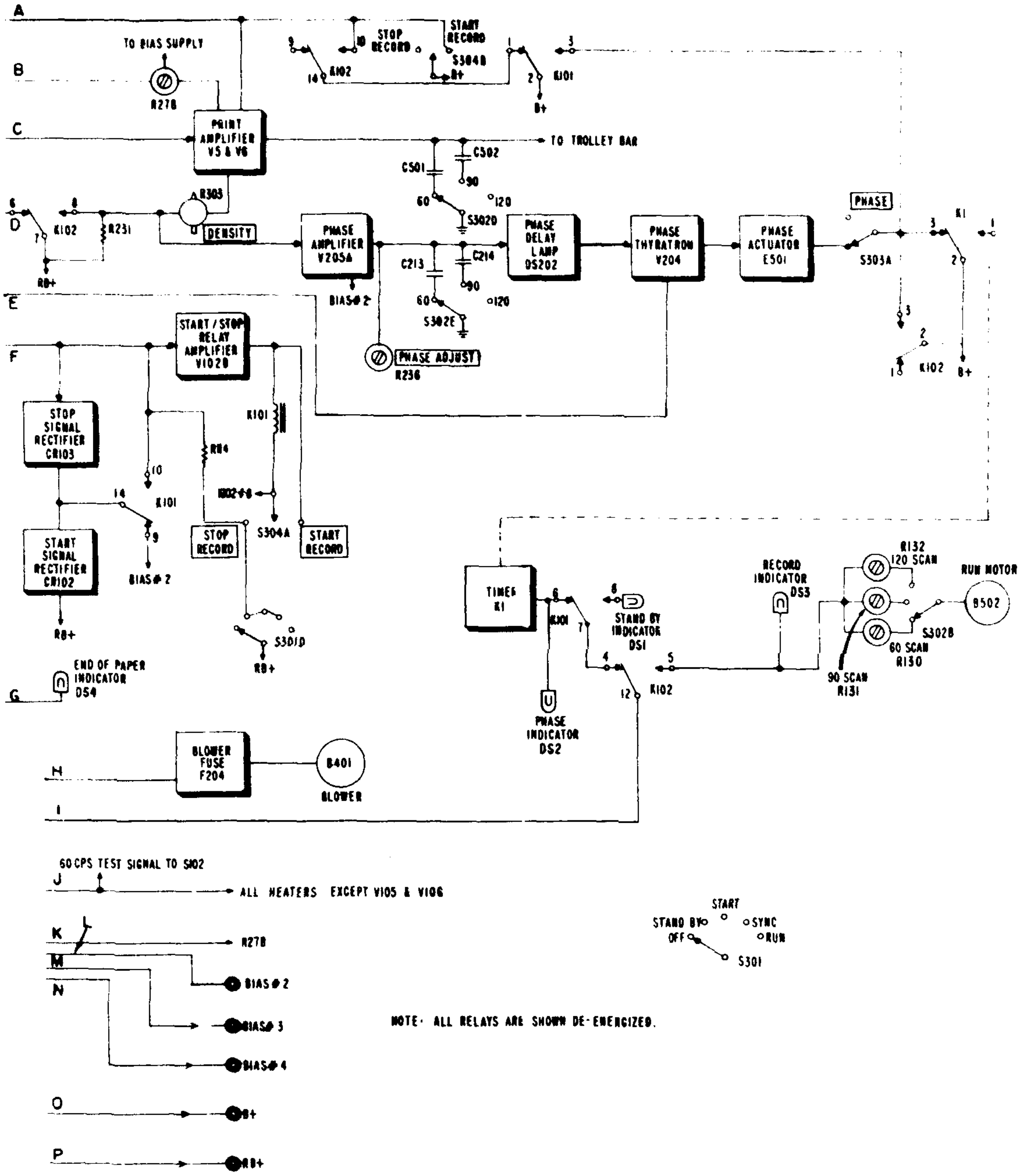

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Figure 10-30.—Facsimile recorder set AN/UXH-2, overall block diagram—Continued.

at the manual position locks out the feedback network, and bias voltage 3 derived from the regulated power supply is applied to the ALC amplifiers. Resistor R301 is then used to adjust the magnitude of the signal input to V1A.

The output signal voltage from V1B is fed to print driver amplifier V4A, then to print amplifiers V5 and V6. Contrast potentiometer R27B is used to control the amount of bias on the grids of V5 and V6. Potentiometer R27A is ganged to R27B so as to vary the signal input to V4A to correspond to the contrast setting, thus maintaining the same recording density. There is no plate voltage on V5 or V6, and consequently no voltage on the trolley bar and stylus needles, until relay K102 is energized.

AUTOMATIC CONTROL CIRCUITS.—When selector switch S301 is turned from OFF to SYNC, start/stop relay K101 is energized by a positive potential applied to the grid of start/stop relay tube V102B to keep the tube conducting and relay K101 energized. This prevents the recording mechanism from starting before S301 is turned to RUN. When S301 is turned to RUN and awaiting a transmission, the positive potential is removed from V102B so that it will respond to the transmitted control signals

The amplified signal output from V4B is fed through high-pass filter FL103 to control signal detector CR104, and out to the automatic start/stop and start-record circuits. When the amplitude-modulated 300-cycle start signal is received, it is detected by CR104, and filtered by FL102 which is tuned to 300 cycles. The 300-cycle output from FL102 is fed to start/stop signal amplifier V101A. The output of V101A is rectified by CR102 to cut off start/stop relay amplifier V102B, and deenergize relay K101. Deenergizing K101 operates contacts to release the armature of phase actuator E501, energize phasing timer K1, and tune FL102 to the 450-cycle stop signal frequency.

After the start signal, phasing pulses are transmitted for 15 seconds. The phase pulse is filtered and fed to the grid of phase amplifier V205A. The amplified pulse output of V205A is fed to phase delay lamp DS202 which fires thyratron V204. Holding current is supplied to phase actuator E501 pulling back the armature. Contacts of timer K1 remain open during phasing, then close maintaining holding current to actuator E501.

When the start record signal is received, it is filtered by FL101 and applied to the start-record signal amplifier V101B. The output of V101B is rectified by CR101 and fed to record relay amplifier V102A. The output of V102A operates record relay K102. Relay K102 operates contacts to apply power to the run motor B502 to start the stylus band rotating. Timer K1 is released, and holding current for the phase actuator is maintained through relay K102 contacts. Plate voltage is applied to print amplifiers V5 and V6, and print power is fed to the trolley bar and stylus needles.

At the end of the transmission the 450-cycle stop signal is detected by CR104 and fed to FL102 (now tuned to 450 cycles). The output from FL102 is amplified by V101A, rectified by CR102, and fed to start/stop relay amplifier V102B energizing start/stop relay K101. The contacts of K101 are restored to the original positions setting up the recorder for the next transmission.

If the set is operated manually, auto/man switch S305A shorts the inputs to the start/stop and start-record signal filters. A positive potential is applied to start/stop relay amplifier V102B by S301D to operate start/stop relay K101. Holding current is applied to the phase actuator E501 through relay K101 and phase switch S303A. When the phasing signal is received, the operator activates phase switch S303, and S303A removes holding current from the phase actuator. Section S303B applies plate voltage to thyratron V204, and phasing pulses fire V204 as described previously. After three phasing pulses the operator releases S303 to reapply holding current to E501.

When copy signals start, the operator throws the start/record switch (S304B) momentarily to start-record. This places a positive potential on the grid of record relay amplifier V102A causing it to conduct energizing relay K102. Relay K102 applies power to the run motor and sets up the set to record.

When the transmission ends, the operator throws the start-record switch momentarily to stop-record. This causes V102B to conduct energizing relay K101. Relay K101 applies holding current to the phase actuator, removes print power from the stylus needles, and stops the run motor.

When the supply of paper is exhausted, the end-of-paper stop switch (S501) operates to remove the RB+ voltage from relay K102 and stop the recording mechanism.

FORK OSCILLATOR AND SYNC MOTOR DRIVE CIRCUITS.—The fork oscillator circuit provides a stable frequency source for the SYNC motor to keep the recorder synchronized with the remote transmitter. The 3600-cycle signal from the fork, Y201, is amplified by V201 and V202, and fed to locked oscillator V203. Oscillator V203 is locked at either 1200, 900, or 600 cycles depending upon the scans per minute to be recorded. The oscillator output is fed through SYNC motor amplifiers V205B, V206, and V207 to the SYNC motor B501A.

SPEAKER AMPLIFIER AND TEST SIGNAL CIRCUITS.—The speaker amplifier circuit is provided for monitoring the facsimile signal. The output from the secondary of T301 is fed through a volume control (not shown) to speaker amplifier V3, and out to speaker LS601.

The test signal circuit is provided for testing and troubleshooting the set. It consists of four switches, and associated circuits which are used to simulate the signals from a remote transmitter.

Operating Adjustments

Operating controls for the AN/UXH-2 are located on the control panel (fig. 10-31). The following steps for automatic and manual operation are listed on the inside of the control panel door.

Automatic operation

1. Select scan speed.
2. Turn to standby and wait one minute.
3. Turn to SYNC and wait 15 seconds.
4. Turn to run—allow SYNC motor to fall into synchronous speed.
5. If SYNC motor does not fall into synchronous speed, repeat steps 3 and 4.
6. Throw auto/man switch to auto.
7. For ALC operation, turn gain control to auto. For manual gain operation, turn gain control to man. and adjust as in step 4 of manual operation.

Manual operation

1. Repeat steps 1 through 4 of automatic operation.
2. Throw auto/man switch to man.
3. For ALC operation, turn gain control to auto. For manual gain operation, turn gain control to man. and adjust as in step 4.
4. On phasing signal, advance gain control from maximum clockwise position until meter reads 100.
5. Hold phase switch down for at least two phasing pulses.
6. When copy starts, throw to start-record.
7. At end of copy, throw to stop-record.

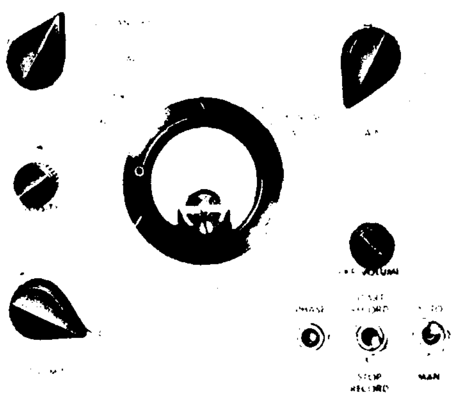

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Figure 10-31.—Facsimile recorder set AN/UXH-2, control panel.

CHAPTER 11

COMMON OPERATING ADJUSTMENTS: RADAR AND LORAN EQUIPMENT

The ET must be familiar with the external adjustments on radar and loran sets.

Radar Set AN/SPS-10D and Loran Receiving Set AN/UPN-12 are used in the following discussions because they are considered to be the most representative sets now in use.

RADAR SET AN/SPS-10D

The AN/SPS-10 (series) is in service on a large number of ships. It is primarily a medium-range, high-definition, surface-search and limited air-search radar. The maximum range when detecting surface targets is normally greater than the optical horizon as received from the antenna reflector. (The optical horizon in miles equals 1.22 times the square root of the antenna reflector height in feet.) The strength of a received echo generally depends on the size and the shape of the target, its distance and altitude, the material of which it is made, and weather conditions.

Radar Set AN/SPS-10D (fig. 11-1) is used primarily in the detection, ranging and tracking of surface targets. It can be used to a limited extent to provide the same information regarding air targets.

Target range and bearing intelligence is displayed on a standard Navy Plan Position Indicator (PPI), such as the AN/SPA-8A. The AN/SPS-10D can be operated as a beacon or with an IFF (identification, friend or foe) system.

The functional operation of Radar Set AN/SPS-10D can be studied with the aid of figure 11-2. The modulator provides modulating pulses for the transmitter, and synchronizing pulses for the other units of the radar system. The transmitter, when triggered by the modulator output, transmits a series or burst of radio-frequency pulses (electromagnetic waves). This energy is radiated by a unidirectional rotating antenna reflector.

Radar Set AN/SPS-10D (fig. 11-1) operates in a frequency range of 5450 to 5825 mc (x-band). The pulsed output frequency is generated by keying a magnetron oscillator in the transmitter. The peak output power is between 190 and 285 kw.

During radar operation the output pulse duration is either 0.25 or 1.3 μs ($\pm$ 10%). The pulse repetition rate (prr) can be adjusted between 625 and 650 pulses per second. Approximately 0.08 μs of each magnetron keying pulse is required to place the magnetron in operation. Thus, the width of the input trigger pulses are 0.33 and 1.38 μs, respectively.

For beacon operation, the pulse duration is increased to 2.25 us, and the prr is decreased to 312 - 325 pulses per second. The total duty cycle of the system (ratio of pulse duration time to pulse repetition time) must be maintained at less than 0.001 to permit magnetron recovery time.

The beacon function of the radar set permits operation of the system in conjunction with responding ships or aircraft. The response signals are mixed in the beacon receiver with the beacon local oscillator output and are ultimately presented on the indicator. The received signal is therefore stronger, and causes bright spots in the indicator pattern. These bright spots are used to identify a responding object.

The antenna rotates at 15 rpm. During radar operation, the horizontal beam width of the radiated pattern is approximately 1.5 degrees. The vertical beam width is within 12 to 16 degrees.

Description And Function Of Units

Figure 11-1 illustrates the major units of Radar Set AN/SPS-10D. You must keep in mind that, on your ship, these units will probably be scattered in various compartments. Make

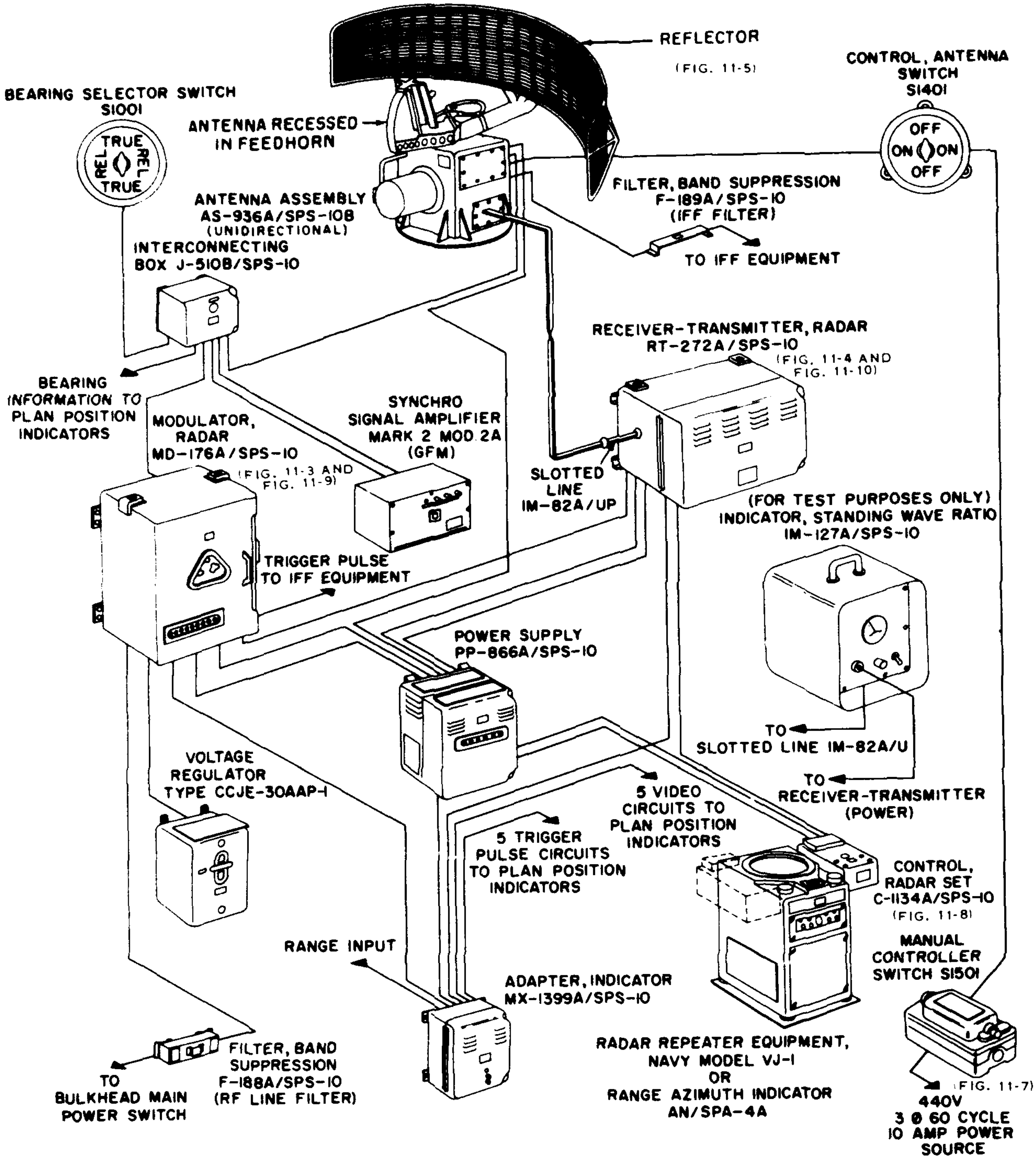

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Figure 11-1.—Radar Set AN/SPS-10D, Pictorial system diagram.

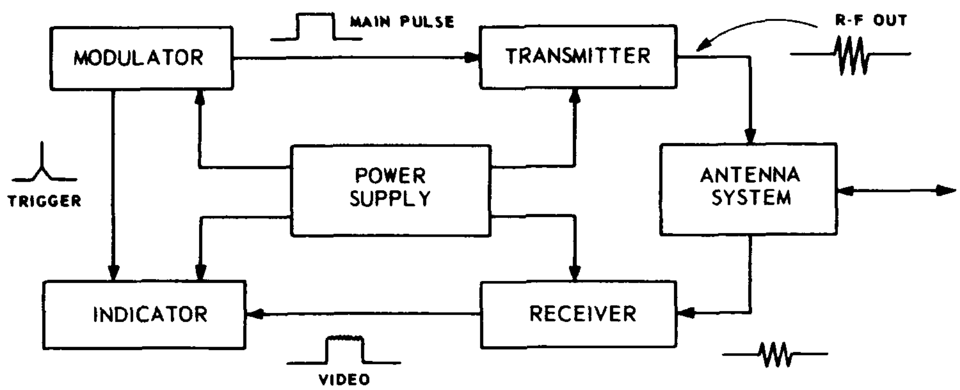

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Figure 11-2.—Radar Set AN/SPS-10D, Functional diagram.

it a point to learn the location of the units on your ship.

FILTER, BAND SUPPRESSION, F-188A/SPS-10 (sometimes called an R-F line filter): This filter serves to eliminate R-F leakage (conducted noise) from the primary power source to the radar set and from the radar set to the primary power source.

FILTER, BAND SUPPRESSION, F-189A/SPS-10 (IFF filter): This filter is connected to the antenna assembly, and minimizes interference from the radar set to the IFF equipment used in conjunction with Radar Set AN/SPS-10D.

VOLTAGE REGULATOR, TYPE CHS-30 AAP-1: The voltage regulator maintains the regulated primary voltage at 115 volts a-c plus or minus 2 percent. It is equipped with a NONREGULATING-REGULATOR ON selector switch so that the voltage regulator may be switched out of the radar system.

A voltmeter is provided for measuring the voltage output of the voltage regulator. A PRESS FOR LINE VOLTAGE pushbutton, when depressed, permits reading the line voltage without taking the voltage regulator out of the radar system, when the selector switch is in NONREGULATING. With selector switch in REGULATOR-ON, meter gives constant indication.

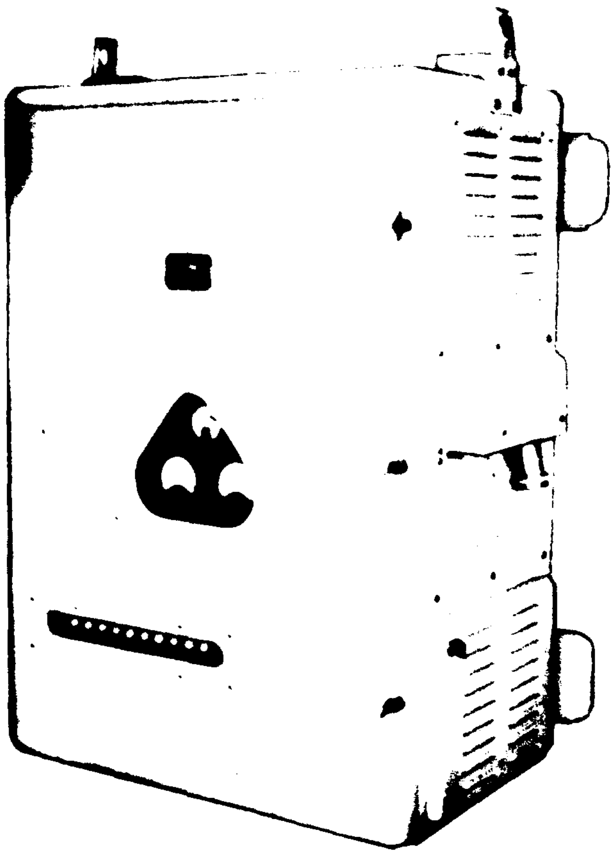
This unit includes its own full-wave d-c power supply for an electronic sensing circuit which controls a motor-driven variable autotransformer connected to an intermediate booster transformer. The booster transformer will either add voltage to or subtract voltage from the voltage delivered by the ship's mains. As a result, a regulated voltage input is maintained to the various circuits of the radar set.

POWER SUPPLY PP-866A/SPS-10: This unit provides four electronically regulated electron tube d-c power supplies for the receiver-transmitter. It also provides one unregulated (low-voltage) d-c power supply for the system control circuits.

When MAIN POWER switch on the radar set control is manually turned to the STDY (standby) position, a 3-minute time delay relay is energized. The delay prevents 115 volts a-c from being fed to the primary side of the power supply transformer of the unregulated power supply. This delay gives adequate time for certain tube filaments to heat sufficiently, thus preventing injury to these tubes when plate voltage is applied.

A blown fuse indicator shunts each fuse of the power supply unit to provide a visual check of its condition. In addition, a warning lamp on the fuse panel is visible when the unit is open, and lights up when the power supply unit is energized. A thermal control switch provides a means of indicating overtemperature conditions by lighting an indicator light at the radar set control. You can get to a 115 volt a-c convenience outlet by opening the front cover of the unit.

MODULATOR, RADAR, MD-176A/SPS-10 (fig. 11-3): The modulator provides the modulating pulse for the transmitter, the synchronizing pulses for the other units of Radar



32.175

Figure 11-3.—Modulator, Radar.

Set AN/SPS-10D, and, in addition, distributes 115-volt, 60-cycle power to the various units.

The modulator contains a trigger pulse generator chassis, a high-voltage switch chassis, a thyratron (keyer) tube chassis, and a rectifier tube chassis. The trigger pulse generator produces trigger pulse voltages of the proper waveform to fire the thyratron tube at a repetition rate of approximately 650 PPS during radar operation. This rate is adjustable from 625 to 650 PPS by means of a motor-driven capacitor which is remotely controlled by a pushbutton on the radar set control.

When the radar set is turned to beacon operation, a resistor-capacitor (RC) network in the high-voltage switch chassis provides a means for reducing the pulse repetition rate of the blocking oscillator in the trigger pulse chassis to half the frequency of the phase shift oscillator, or about 325 PPS.

A motor-driven, high-voltage, pulse-width switch selects one of three pulse widths (0.25-microsecond short pulse, 1.30-microsecond long pulse, or a 2.5-microsecond beacon pulse plus or minus 10%).

Low-amplitude samples of the modulating pulse, used to modulate the magnetron oscillator in the transmitter, are supplied to trigger and synchronize the indicator adapter. The modulating pulse and the trigger pulses are sent from the modulator through coaxial cables. These cables are connected to the jack assembly contained in the protective shield attached to the right side of the modulator cabinet.

A motor-driven blower and air cleaner (filter) provide ventilation for getting rid of heat generated by the modulator.

The power distribution circuit consists of an autotransformer, relays, a safety switch, and 11 fuses with blown fuse indicators.

Three meters are mounted on a hinged panel behind a viewing window in the front door of the unit. These are: (1) a time meter which shows directly the total number of hours during which the equipment is on; (2) a time meter which shows directly the number of hours during which the equipment is in the radiate condition; and (3) a milliammeter which measures relative magnetron average current for long-pulse, short-pulse, and beacon-pulse operation.

INTERCONNECTING BOX J-510A/SPS-10: The interconnecting box serves (by means of its internally connected terminal boards) as a junction point for the modulator, synchro signal amplifier, antenna assembly, and radar repeater equipment (one master indicator and four remote repeaters).

The interconnecting box contains two capacitors for improving the power factor of the 1-speed and 36-speed synchros, a stepdown transformer which provides the proper voltage for the relative bearing warning light at the radar repeater equipment, and a selector switch for feeding either true or relative bearing information to the radar repeater equipment.

RECEIVER-TRANSMITTER, RADAR, RT-272A/SPS-10D. The receiver and transmitter are housed together in one cabinet (fig. 11-4).

The receiver portion of this unit is mounted on a specially shielded, readily accessible, hinged panel inside the front cover. A hinged auxiliary control panel for local control is located above the receiver panel.

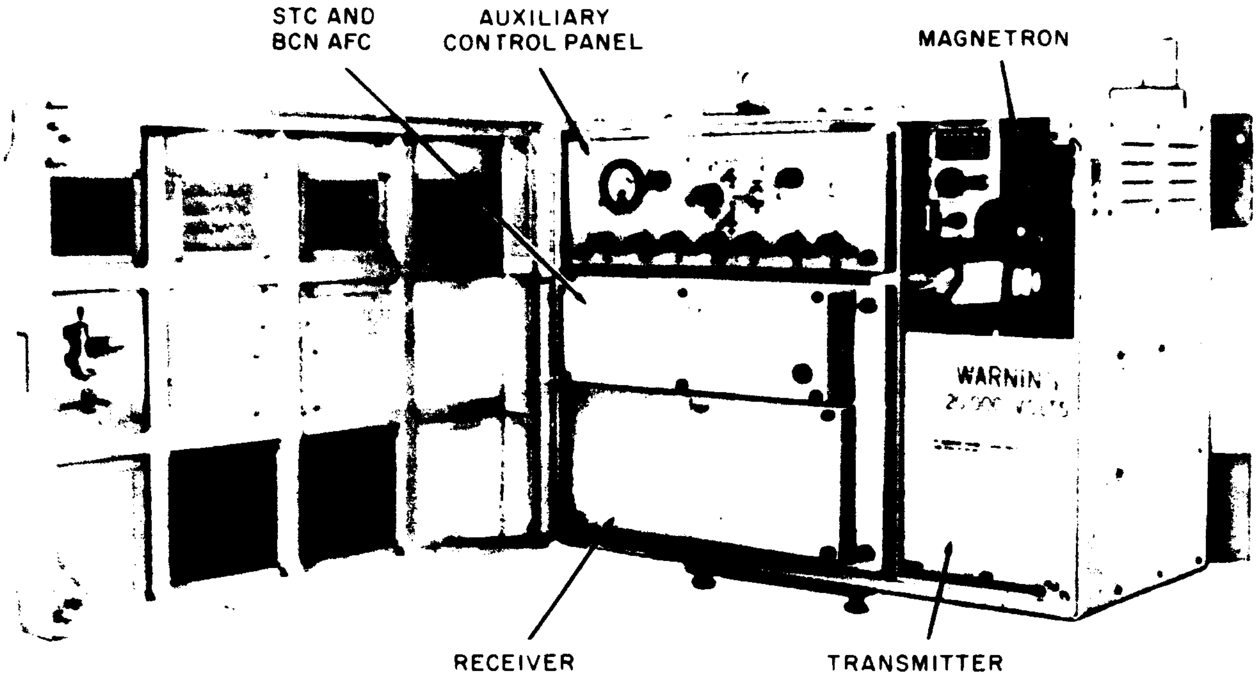


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Figure 11-4.—Receiver-Transmitter, Radar, Major units, Access door open.

The transmitter, with its associated equipment, is mounted in the receiver-transmitter cabinet behind the receiver panel and auxiliary control panel.

The receiver uses two local oscillators, one for radar operation and the other for beacon operation. By means of a selector switch on the radar set control, the receiver may be placed in either radar or beacon operation. The receiver contains broad-band I-F strip video stages, IAGC (instantaneous automatic gain control) circuits for reducing interference from strong returned signals, an FTC (fast time constant) circuit which can be used with or without IAGC to distinguish land-masked targets, an STC (sensitivity time control) circuit which reduces receiver gain for signals from targets at short range and yet maintains full gain for signals from targets at greater range, and separate AFC (automatic frequency control) circuits, one for radar and one for beacon operation.

The transmitter consists of a high-voltage pulse transformer, a magnetron oscillator, a duplexing system which includes a TR tube for protecting the receiver from excessive input during the transmission period, two ATR tubes to prevent a loss of received energy in the magnetron, a mixer, an echo box, a blower to provide a means of cooling, and other equipment such as the probe for the slotted line, interlocks, and fuses. An opening in the upper left side of the receiver-transmitter permits the slotted line or waveguide transmission line to be bolted directly to a waveguide flange on the duplexer.

An echo box (resonance chamber), located in the receiver-transmitter, can be tuned either by means of a toggle switch on the radar set control which operates the control motor of the echo box, or by means of a manual tuning knob attached to the shaft of the echo box motor.

The echo box constitutes a high Q (quality or figure of merit) tuned circuit at the transmitter frequency whose energy storage properties are used to provide an artificial echo on the plan position indicator. This artificial echo gives an indication of the overall performance of the radar set.

The auxiliary control panel contains the following equipment and controls: an ECHO BOX TUNE knob, a LOCAL-REMOTE switch,

an STC (ON-OFF) switch, an RDR BCN-AFC (ON-OFF) switch, an OFF-RADIATE-START switch, and a milliammeter and selector switch for measuring beacon AFC crystal current, radar AFC crystal current, magnetron current, receiver crystal current, and video detector current. It also includes seven manual controls, located near the bottom of the panel, that have the following adjustments: receiver tuning, beacon tuning, receiver gain, video detector zero set, STC duration, STC magnitude, and STC flat control.

SLOTTED LINE IM-82/UP: The slotted line (also called slotted waveguide) is a section of rectangular waveguide which bolts to the flange of the duplexer located in the upper left side of the receiver-transmitter.

This unit provides a means for making standing-wave measurements. The top surface of the slotted line has a slot cut through it and is provided with a sliding cover. The slot should be covered when measurements are not being taken. An R-F probe, normally stored on the inside of the door of the receiver-transmitter, is connected to an amplifier and a meter and is inserted into the slot to make the measurements.

ANTENNA ASSEMBLY AS-963A/SPS-10B: The antenna assembly (fig. 11-5) includes a truncated parabolic reflector, feedhorn, IFF dipole, IFF loadmatching section, IFF corner

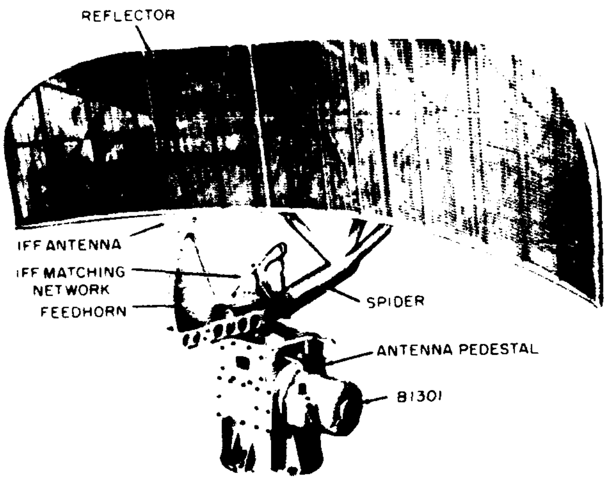

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Figure 11-5.—Antenna assembly AS-936A/SPS-10B.

reflectors, spider and pedestal SB-561A/SPS-10B. The radar horizontal beam width is about 1.5°, whereas the IFF horizontal beam width is about 6°.

The antenna pedestal rotates the Antenna Assembly in a clockwise direction at a speed of 15 rpm. The pedestal consists of a cast steel housing containing an upper rotating rotary joint, a lower stationary rotary joint, an antenna drive motor, a 5 G synchro, a thermostat and heater to control oil temperature, a gear train, and a pair of cam-actuated microswitches to operate the ship's heading marker circuit. The antenna requires a power source of 440 volts, three phase, 60 cycles, at 10 amperes.

Three switches (fig. 11-1) that function in conjunction with the antenna are the Bearing Selector Switch S1001, the Control, Antenna Switch S1401, and the Manual Controller Switch S1501 (discussed later).

The Bearing Selector Switch is a remote control whose function is to feed either true or relative bearing information to the Radar Repeater equipment. It is a double-pole single-throw rotary type snap switch, located adjacent to the Radar Set Control.

The Control, Antenna switch removes power from the antenna drive motor, thereby disabling the antenna and allowing maintenance personnel to safely perform necessary maintenance procedures. It is mounted on the ship's mast below the antenna assembly, and is employed as a safety measure. The switch is a snap-action, two-position, 2-ampere, 450-volt a-c rotary packet switch with markings OFF and ON engraved on the switch to indicate its positions.

ADAPTER, INDICATOR, MX-1399/SPS-10: The indicator adapter contains its own power supply, a ship's heading marker circuit, a video amplifier circuit, a trigger pulse delay circuit, and video mixer circuit for range marks.

The video amplifier stages provide enough video power amplification of the echo video pulses to give five identical low-impedance outputs. These outputs may be distributed individually to five standard Navy plan position indicators.

The trigger pulse delay circuit has an adjustable compensating time delay between the transmitted microwave pulse and the trigger pulse generated by the modulator. The trigger pulse time delay is accomplished by the combination of several low-pass filter networks. Forty-eight sections provide a total time delay

of 2.4 microseconds in steps of 0.05 microsecond each.

The delayed trigger pulse is amplified and fed to five cathode followers which supply five identical synchronizing trigger pulses for triggering indicator repeaters.

An amplifier and a multivibrator circuit furnish the ship's heading marker signals for mixing with the video signals. Provisions are also made for mixing a positive 5-volt range marker signal with the video signal.

The power supply provides both plate and bias voltages for the unit. The unit has a fuse and a blown fuse indicator for its 115-volt, 60-cycle input supply.

CONTROL, RADAR SET, C-1134/SPS-10: The radar set control, called the general control unit on many radars, contains all necessary controls for operating the radar system.

The infrequently used controls are located near the top of the front panel behind a hinged cover. These controls are: STC magnitude, STC duration, STC flat, antijam selector switch, pulse repetition rate (PRR) control switch, and a ship's heading marker (SHM) ON-OFF switch.

The normal operating controls mounted openly on the front panel are: an echo box switch, toggle switch, three overtemperature indicating lights (modulator, receiver-transmitter (RT), and power supply (PS); a d-c monitoring meter with selector switch for measuring receiver crystal current, radar and beacon AFC crystal current, magnetron current; a main power switch; a pulse-width selector switch (BCN radar); an AFC (ON-OFF) switch; an STC (ON-OFF) switch; and adjustments for receiver gain and receiver tuning. The control identifications are illuminated for dark space adaptation; a dimmer controls the intensity of the illumination.

The radar set control can be mounted on either side of the indicator of Radar Repeater Equipment, Navy Model VJ-1 or Range Azimuth Indicator AN/SPA-4A.

ACCESSORY EQUIPMENT: A standard Navy plan position indicator (Radar Repeater Equipment, Navy Model VJ-1) and a Synchro Signal Amplifier Mk 2 Mod 2A may be used with the radar set.

The AN/SPA-4A and/or AN/SPA-8A is a radar repeater that is replacing most VJ's, and is suitable as a master indicator or a remote indicator. It is designed for use with any type of naval search radar capable of presenting range and bearing information.

FUNCTIONAL BLOCK DIAGRAM

The detailed functional block diagram, figure 11-6, shows all of the major units of Radar Set AN/SPS-10D. The main system flow is indicated by heavy lines, and supplementary circuits by light lines.

The following consideration of the block diagram emphasizes the purpose and relationship of all major units of the radar system. A detailed block diagram of each major unit is presented before the discussion of the major circuits of that unit.

Synchronizing trigger pulses for the radar set are obtained from the modulator. The primary a-c power is fed to the modulator through an r-f line filter. This filter serves to eliminate the transfer of r-f noise from the a-c power source to the radar set and from the radar set to the power source.

An electronically controlled voltage regulator maintains the a-c power input voltage at 115 volts ± 2 percent. A power supply converts the a-c input voltage into regulated and nonregulated d-c voltages for distribution to the various circuits.

The modulator pulse output is formed in any one of three pulse forming networks each of which produces pulse outputs of different time durations. The main pulse output is a negative-going rectangular pulse which is fed to the transmitter. The transmitter then develops r-f pulses of either 0.25, 1.30, or 2.25 μs as determined in the pulse forming network selected at the modulator. The length of the transmitter trigger pulses is sufficient to compensate for the delay in the starting of the transmitter.

The negative pulses (main pulses) generated in the modulator are applied to a pulse transformer in the transmitter, where the amplitude is increased from 5 kv to approximately 20 kv. The pulses from the transformer are applied to a magnetron oscillator with no change in the original waveform polarity. Application of the pulses to the magnetron places the magnetron in operation, and causes it to generate microwave r-f energy for a time interval equal to the length of each input pulse, minus the time required to key the magnetron (0.08 μs).

The modulator also provides low amplitude samples of the main pulses. These pulses are

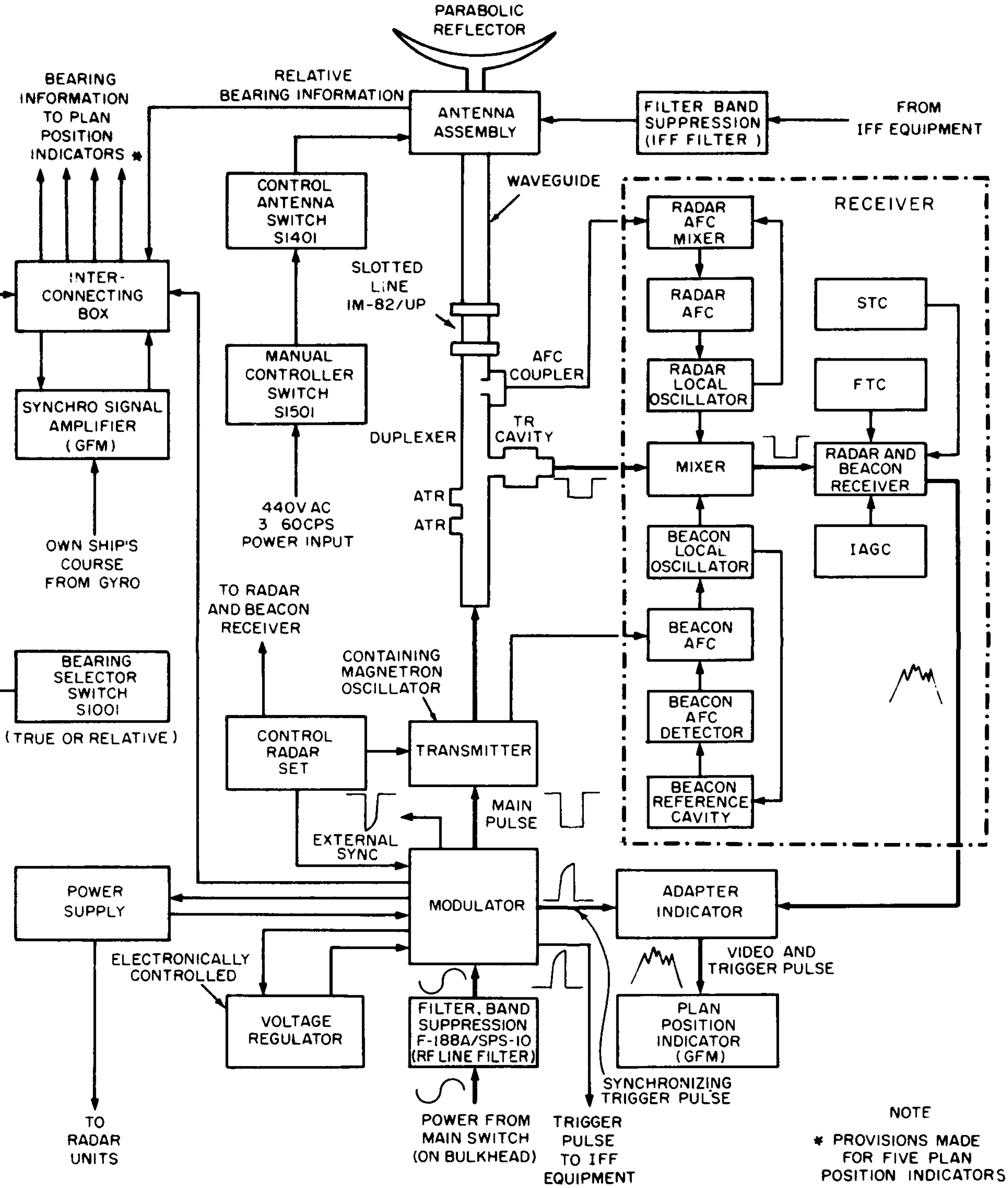

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Figure 11-6.—Detailed functional block diagram.

applied along one path to an adapter indicator. Other samples of the main pulse from the modulator are used for synchronizing external and auxiliary equipments which may operate in conjunction with the radar set.

In the adapter indicator, the trigger pulses are delayed to compensate for the time delay between the trigger pulse generated by the modulator and the actual transmission of the microwave r-f pulse. After delay, the trigger pulse is amplified and applied to five conventional cathode-followers. The output pulses are used separately to trigger as many as five plan position indicators.

The microwave r-f output energy of the magnetron oscillator is conducted to the antenna assembly through a duplexer, a slotted line, and a rectangular waveguide. This energy is then directed by a feedhorn (fig. 11-1) to the surface of a slotted parabolic reflector.

During transmission, the antenna reflector concentrates and radiates the energy into space in a narrow beam pattern. The pattern forms a horizontal angle at the reflector of approximately 1.5 degrees and a vertical angle of from 12 to 16 degrees. The antenna pattern is formed by phase addition and subtraction of the microwave r-f energy components radiated to its surface by the feedhorn.

The antenna rotates at 15 rpm. The transmitted beam sweeps over the surrounding area to search for both surface and airborne targets within the limits of the antenna reflector.

When the radiated energy strikes a target, a small portion returns to the antenna reflector. The reflector directs this reflected energy to the receiver (fig. 11-6) through the waveguide, slotted line, duplexer, and t-r cavity. The t-r cavity acts as an automatic electronic shorting switch to block the receiver from the high energy r-f pulses of the transmitter while the transmitter is radiating, and to unblock the receiver to the waveguide while the transmitter is not radiating.

Two a-t-r (anti-t-r) tubes, located near the magnetron oscillator in the transmitter, present a high impedance to the returned signal energy (echo), thus preventing dissipation of the returned signal at the magnetron oscillator during the receiving interval.

The returned echo is fed to a mixer stage, where it is mixed with a signal from either the radar or beacon local oscillator. The radar local oscillator operates on a frequency 30 mc higher than the returned signal frequency or 5480 to 5855 mc. The beacon local oscillator operates at a single frequency (5420 mc) or 30 mc below the received beacon signal. For either radar or beacon operation, the difference frequency component at the output of the mixer is selected and amplified by the i-f amplifiers in the receiver.

Since the radar and beacon local oscillators are coupled to the same mixer, the use of a common i-f amplifier section for either radar or beacon reception is possible. Either the radar or beacon local oscillator is turned on independently for the desired type of operation.

After amplification and detection in the receiver, a video output signal from the receiver is delivered to the adapter indicator. The output from the adapter indicator can be used to operate as many as five plan position indicators.

The adapter indicator output is applied to the control grid of the cathode-ray tube in the PPI and causes intensity modulation of the electron beam. The target signal is thus converted into visible intelligence on the screen of the PPI scope, where it appears as a bright spot.

Automatic frequency control (afc) circuits are provided for the radar and beacon local oscillators. The function of the radar afc circuit is to maintain the frequency of the radar local oscillator 30 mc higher than the magnetron frequency, regardless of minor drifts in the magnetron frequency. The radar afc circuit compares the radar local oscillator and magnetron frequencies in a circuit which produces a voltage to correct the radar local oscillator for the proper intermediate frequency. The beacon afc circuit ensures that the beacon local oscillator operates 30 mc below the magnetron frequency during beacon operation.

The sensitivity time control (stc) circuit is of value in reducing saturation of the i-f stages due to strong echoes from the sea at close ranges (sea-return saturation) so that nearby targets can be distinguished. The stc circuit reduces the gain of the receiver instantaneously in coincidence with each transmitted pulse. The gain is reduced for only a short period of the sweep time and is permitted to rise exponentially to normal gain so that weak echoes from distant targets will receive normal amplification in the receiver. The stc circuit does not affect the presentation on the

plan position indicator of targets which are beyond the stc range. The time interval needed to fully restore the receiver gain limits the period over which the stc can remain effective after each transmitted pulse.

The fast time constant (ftc) circuit makes it possible to distinguish more clearly individual small targets (short duration) in an area of large targets having considerably longer durations. This feature is useful when there are many strong close-in targets. The ftc circuit differentiates all return signals in a short time constant circuit and causes each signal to be of approximately equal duration.

An instantaneous automatic gain control circuit (iagc) prevents strong signals from saturating the i-f amplifiers. The iagc circuit reduces the gain of the i-f amplifiers for the duration of the strong received signal.

The bearing selector switch provides a means of selecting either true or relative bearing information for presentation on the plan position indicators. Relative bearing information is fed from an antenna synchro (not shown) through the interconnecting box to the plan position indicators. Relative bearing information is also fed to the synchro signal amplifier.

The synchro signal amplifier combines the relative bearing information from the antenna synchro and own ship's course information from the ship's gyro compass to present true bearing information on the plan position indicators.

The manual controller switch (Fig. 11-7) is a power switch used to start and stop antenna rotation. The switch also contains an overload relay which removes power from the antenna when the current reaches an overload value. The control antenna switch also removes power from the antenna and is mounted on the ship's mast below the antenna. The switch is intended for use by maintenance personnel to remove antenna power during maintenance procedures.

The IFF filter minimizes interference from the radar set to the IFF equipment which may be used in conjunction with the AN/SPS-10D.

OPERATION OF THE AN/SPS-10D

Safety features have been installed on the radar set for protection of operating personnel and the radar set itself. However, it is absolutely necessary that the Technician or operator practice all safety precautions whenever using the set or making adjustments.

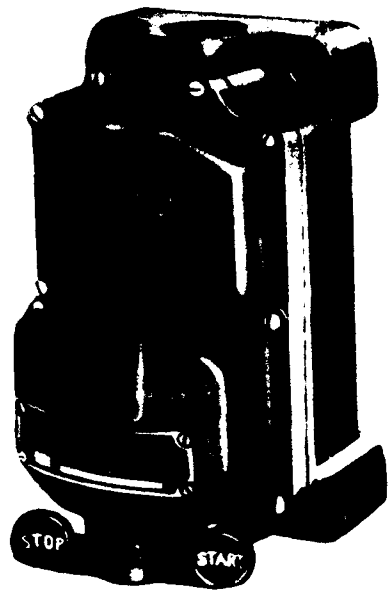

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Figure 11-7.—Manual controller switch S1501.

You should familiarize yourself with the operation of this equipment, concentrating on the function and location of all operating controls. Learn the procedure on the instruction plaque that you will find located near the radar set control.

Be sure to follow the operating procedures for equipment accessory to the AN/SPS-10D outlined in the instruction books for the standard Navy plan position indicator-the AN/SPA-4A on the AN/SPA-8A.

Prechecks

WARNING—High voltage is used in the operation of this equipment. Death on contact may result if personnel fail to observe safety precautions.

1. MAIN POWER: Before the equipment is placed in operation and the main power switch on the bulkhead (which controls primary power to the radar set) is turned on, all safety interlocks must be closed. The battle short switch in the modulator and the main power switch on the radar set control (fig. 11-8) should be placed in the OFF position. The drive motor disabling switch on the antenna assembly must be in the ON position.

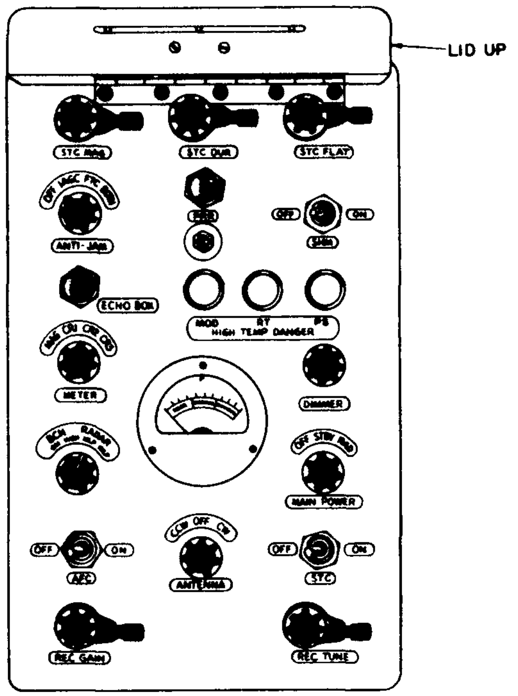

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Figure 11-8.—Radar set control—front panel controls.

2. ANTENNA OIL HEATER: A thermostatically controlled heater is provided in the oil compartment of the antenna gear box. It prevents the lubricant from thickening in cold weather. The oil heater can be turned off only by turning off the main power switch to the radar set (on bulkhead).

3. BLOWERS: A blower is provided in the modulator and in the receiver-transmitter to circulate air during periods of operation. The two blowers are immediately energized when the main power switch, located on the radar set control, is in either standby or radiate position. Additional protection for magnetron cooling is provided by an air flow switch. Failure of the blower in the receiver-transmitter closes the air flow switch causing the HIGH TEMP DANGER (RT) indicator light to glow.

4. LOCAL-REMOTE AND OFF-RADIATE-START SWITCHES (auxiliary control panel): During normal operation of the radar set control, make certain that the local-remote switch is on REMOTE and the off-radiate-start switch is on RADIATE.

5. EMERGENCY STOP: To turn off the equipment in an emergency, the following methods can be used:

a. Turn main power switch on the radar set control to the OFF position.

b. Turn main power switch to the radar set (on bulkhead) to the OFF position.

CAUTION.—If the main power switch to the radar set (on bulkhead) is used to turn off the equipment in an emergency during cold weather, it should be turned back on without delay because damage may occur to the antenna gear box due to thickening of lubricant.

Operational Checks

To start, make the following checks to prevent damage to the radar set by improper operation.

1. Check the overtemperature indicators (table 11-1) on the radar set control (fig. 11-8). If any of these indicators glow, turn off the radar set. In an emergency, operation may continue for a limited time.

Table 11-1.—Overtemperature Indicators.

Designation	Location	Color of light
PS	Radar set control	Red
RT	Radar set control	Red
MOD	Radar set control	Red

2. Check the magnetron current on the transmitter current meter located in the modulator (fig. 11-9). It should read in the NORMAL portion of the meter scale. If the meter reads in the DANGER portion of the scale, the equipment must be shut off immediately.

In an emergency, operation may continue for a brief time.

Starting the Equipment

The following procedures must be followed, otherwise damage may occur to the set.

1. Check that the main power switch to the radar set (on bulkhead) is ON. This switch must remain on at all times.

2. Check that the following control switches are in the indicated positions:

a. MAIN POWER switch on the radar set control at OFF.

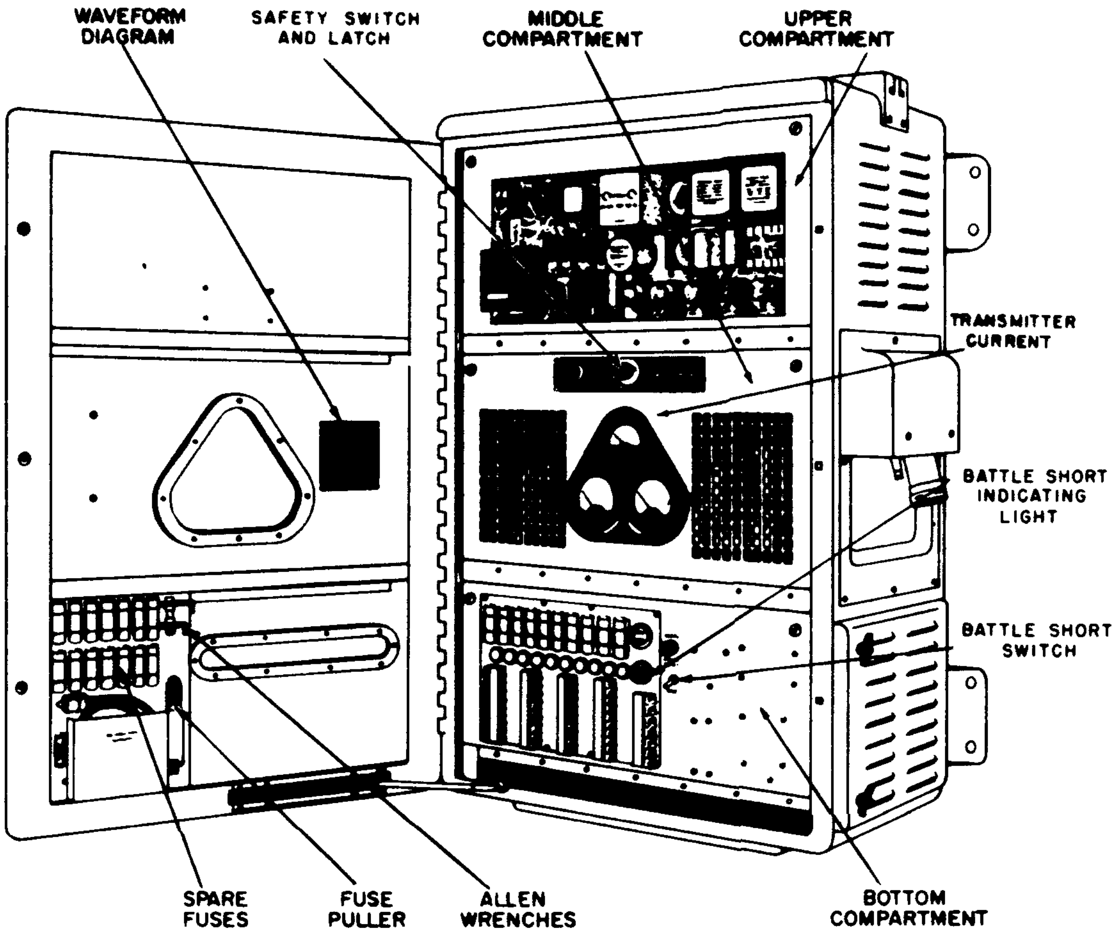

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Figure 11-9.—Radar modulator—front panel controls.

b. BATTLE SHORT switch on the modulator at OFF.

c. NONREGULATING-REGULATOR ON switch on the voltage regulator at NONREGULATING.

3. Check that the following control switches on the auxiliary control panel of the receiver-transmitter are in the indicated position (fig. 11-10):

a. OFF-RADIATE-START switch at RADIATE.

b. LOCAL-REMOTE switch at REMOTE.

4. Turn the main power switch on the radar set control to STBY. Adjust the intensity of the panel illumination to the desired brilliance using the dimmer control.

5. Turn on the plan position indicator and synchro signal amplifier. Refer to their instruction books, if necessary.

6. At the voltage regulator depress the PRESS FOR LINE VOLTAGE switch and read the line voltage on the meter. The line voltage should be 115 plus or minus 10 percent (103.5 volts a-c to 126.5 volts a-c). If the line voltage is outside this operating range, deenergize the radar set.

7. Turn the NONREGULATING-REGULATOR ON switch on the voltage regulator to the REGULATOR ON position.

8. At the voltage regulator, read the regulator output voltage on the meter. The regulated voltage should be 115 plus or minus 2 volts. (The meter reads the regulated output voltage

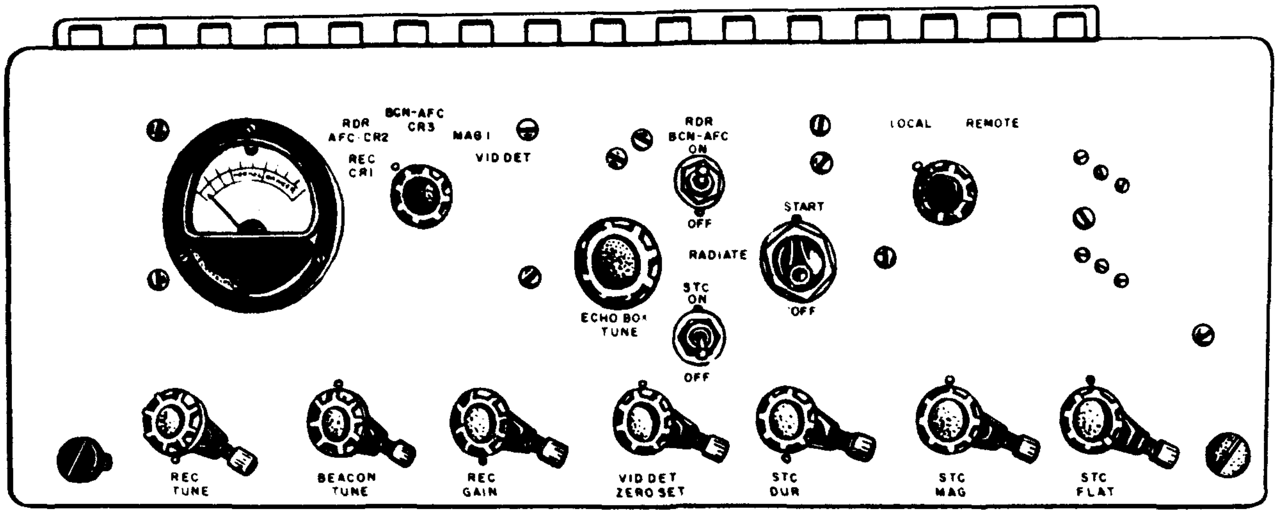

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Figure 11-10.—AN/SPS-10 receiver-transmitter—auxiliary control panel, front panel controls.

when the PRESS FOR LINE VOLTAGE switch is NOT depressed.

9. Turn the ANTENNA switch at the radar set control to the desired position (CW or CCW).

10. Turn the TRUE-RELATIVE bearing switch on the interconnecting box to the desired position (TRUE or RELATIVE).

11. Three minutes after switching to STBY, turn the main power switch to RAD.

12. Turn the BCN-RADAR selector switch at the radar set control to the desired position. See table 11-2.

Table 11-2.—Radar Selector Switch Positions.

Position	Purpose and pulse types
WSP	Wide receiver bandwidth, short pulse, least range, high definition.
WLP	Wide receiver bandwidth, long pulse, medium range, good definition.
NLP	Narrow receiver bandwidth, long pulse, longest range, least definition.
ON	Beacon operation.

13. Check that the following control switches on the radar set control are in the indicated positions:

a. AFC switch at ON.
b. STC switch at OFF.
c. ANTI-JAM switch at OFF.

14. Adjust the REC GAIN control on the radar set control and the appropriate controls on the plan position indicator to obtain the desired presentation.

15. Special operating features STC, IAGC, and FTC can be energized at the radar set control. These controls should not be used except for the conditions described. Remember that other stations usually use the same radar for other purposes, such as the officer of the deck, for example, to keep the ship on station while in formations. If you play with these controls, you might endanger the ship.

Tuning Adjustments

1. Receiver tuning (radar set control):
   a. Place the radar set in normal operation.
   b. Check that the following controls are in the indicated positions:
      (1) AFC switch to ON.

(2) BCN-RADIATE switch at WSP, if switch is set in this position, radiation must be turned off before changing.
(3) STC switch at OFF.
(4) ANTI-JAM switch at OFF.
(5) ANTENNA switch at CW.
(6) REC GAIN control at the position which gives the desired presentation on the plan position indicator.

c. Turn the METER selector switch to MAG. The meter should read in the NORMAL portion of the scale. If the meter reading is abnormal, repair is indicated.
d. Turn the METER selector switch to CR1 (receiver crystal current).
e. A steady meter reading indicates that the receiver is tuned. If the meter reading flutters, adjust REC TUNE to obtain a steady reading; then secure the REC TUNE knob.
f. Turn the METER selector switch to CR2 (radar AFC crystal current). If the meter reading is not between 0.4 and 0.6 milliampere, repair is indicated.
g. Energize the echo box motor by depressing the ECHO BOX pushbutton switch. (This motor remains energized until the ECHO BOX pushbutton is again pressed.)
h. Echo box ring time should be greater than 4000 yards for BCN-RADAR switch positions WSP, NLP, and WLP, with REC GAIN control set at full gain. If the ring time is less than 4000 yards for any of these positions, repair is indicated.

2. Beacon receiver tuning check. Follow rocedures given · receiver tune.

3. Adjustment of STC controls: The STC ontrols require adjustment from time to time allow for different conditions of sea return, epending on the roughness of the sea. The ea return appears on the plan position indiator as a solid disc extending radially for a nge of several miles. The following procedure suggested for an approximate setting of the ontrols. Final adjustments will probably have be made by trial and error.

a. Start the equipment
b. Tune the receiver.
c. Set the REC GAIN control to obtain the best presentation on long-range targets.
d. Turn the STC switch to ON.
e. Turn the STC FLAT control near its midposition.
f. Turn the STC DUR control fully CCW.
g. Adjust the STC MAG control to break up the solid disc at the center of the plan position indicator into individual targets.
h. Turn the STC FLAT control fully CCW so that the solid disc reappears at the center of the indicator. Then slowly turn the STC FLAT control clockwise until the solid disc barely disappears.
i. Adjust the STC DUR control to best define the targets slightly beyond the solid disc.

LORAN RECEIVING EQUIPMENT

The principle of operation of the loran system of obtaining navigational fixes is described briefly in chapter 5 of this training course. A loran receiver located aboard ship is used to determine the difference in time required for pulsed radio signals to arrive from a pair of synchronized transmitters (master and slave stations simultaneously pulses) installed on shore several hundred miles apart.

LORAN RECEIVING SET AN/UPN-12

The AN/UPN-12 Loran Receiving Set (fig. 11-11) is a navigational aid that gives a direct reading in microseconds (at the loran receiver) of the time difference in arrival of signal pulses from master and slave transmitters of a loran transmitting group. In the loran system it is neither necessary (1) to know the exact location of the transmitting station, nor (2) to measure the direction of arrival of the radio signals.

The antenna signals are fed into the r-f circuit through an antenna coupler, an antenna tune switch, S1, and an attenuator. When S2 is in the distant position, signals bypass the attenuator. The antenna may be either a wire or whip type and the antenna coupler is used to match the input impedance for optimum signals. The desired set of loran stations is selected by means of a channel control switch, S3 (fig. 11-12,) which selects one of four

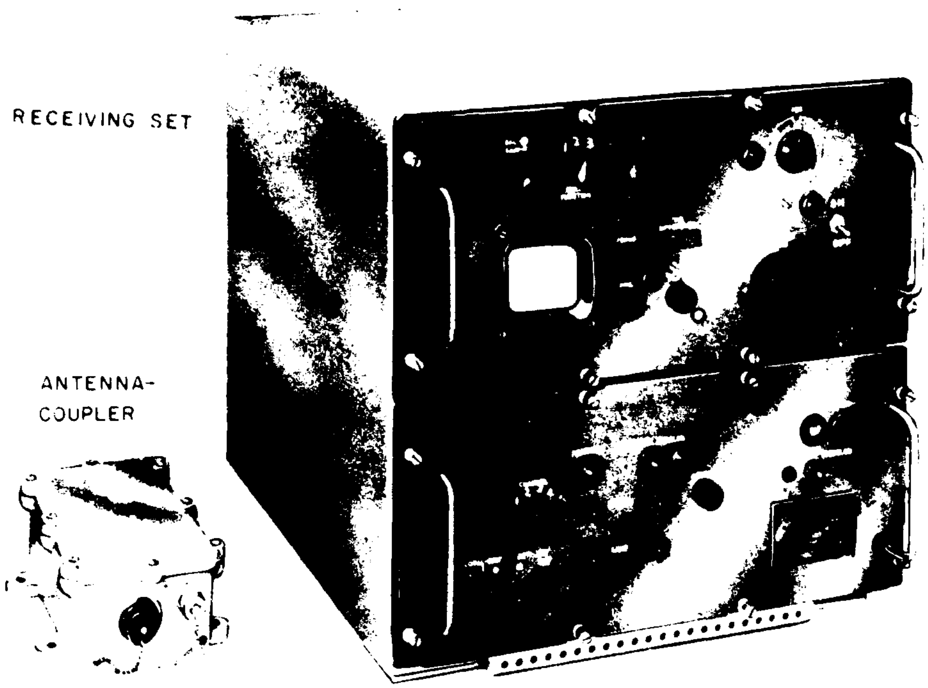

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Figure 11-11.—Loran Receiving Set AN/UPN-12.

available channels. The input signals are amplified in the r-f amplifier, V1; heterodyned in a crystal controlled converter, V2; again amplified in two stages of i-f amplification (V3 and V4) and detected in V5A. The input signal level to the r-f amplifier stage, V1, is controlled by a three-position, local distant (L-I-D) switch, S2.

The detected pulses from V5A (fig. 11-12) are coupled through video amplifier-limiter V6A and a high-pass filter, to video amplifier V6B. A clipper stage, V5B, eliminates negative portions of the V6A output. Since the V6B output is applied through another video amplifier, V7, to the indicator tube, V60, the action of clipper stage V5B eliminates the portion of the V60 input below the established reference.

An antijam switch, S4, functions to reduce the effects of jamming by removing low-frequency components of the video signal. High-frequency components are retained to preserve the rise time (leading edge) of the input pulse.

The video output of V6B is coupled along dual paths to the video amplifier, V7, and to video amplifier V10. The V7 output is applied to the indicator tube, V60, as discussed. The V10 output is applied to the A and B gate stages, V11 and V12, respectively, and is effective in controlling the automatic frequency control circuits.

The positive output of the pedestal amplifier, V55, is applied to the A multivibrator, V8, in the frequency control circuits. The frequency control stages synchronize the repetition rate of the receiving set with that of the received signals to hold the pattern displayed on the indicator stationary while readings are being taken. Either automatic or manual frequency control is used, depending upon the setting of the AFC switch, S5.

When AFC is used, the repetition rate of the incoming signals is compared with the receiving set repetition rate in stages V9 through V15. The error voltage derived from the comparison at the discriminator, V15, is used to hold the receiving set pulse rate and the rate of the received signals in synchronism. When manual control is desirable, the AFC switch (fig. 11-12) is placed to OFF. Fine control of the receiving

set pulse repetition rate is then determined by the drift control, R86.

The time base of the receiving set is produced by an 80-kc sine wave crystal-controlled oscillator, V17 (fig. 11-12). The oscillator output is shaped in a ringer stage, V18, and clipped in V19 to produce sharp negative driving pulses for a group of 11 counter stages, V20 through V30. Actually 12 counter stages are used. The action of the twelfth counter, V31, is considered presently. The oscillator, V17, is reactance-tube controlled by V16, whose input is the error voltage derived from the comparison of the receiving set repetition rate, and the rate of the received signals at the discriminator, V15, as discussed.

Frequency division is used in the counter stages, V20 through V31, to produce a square wave at each counter output, which is one-half the frequency of its input. Each of the counter stages is an Eccles-Jordan multivibrator.

The square waves at the plates of the third to eleventh counter (V22 to V30) are employed in the repetition rate and variable delay circuits. The 10-kc (100 us) output of the third counter is coupled to the shaper, V50A (a part of the variable delay stages), and the 1600-us output of the seventh stage, V26, is coupled to the fixed delay stages.

In the pulse repetition rate circuits the input square waves from the third to eleventh counter stages (V22 to V30) are combined in a reset thyratron tube, V37, to produce a positive and negative reset pulse when the predetermined count selected by the PRR switch, S6, is reached. The positive reset pulse is used to trigger all of the counter stages, V20 through V31, thereby resetting the counter stages to start a new cycle. The negative reset pulse is used to drive the sweep generator, V57, and the blanking d-c restorer, V59.

The recurrence frequency of the reset pulse from V37 is twice that of the received signals. However, each negative reset pulse from the V37 plate (as seen later) triggers the twelfth counter stage,-V31, which produces the final output frequency of the counter chain. Thus, since two input pulses are required to produce a single output pulse from the counter chain, the period of the output of the twelfth counter, V31, is equal to the period of the received signals.

The twelfth (final) counter (V31) plates produce two square waves of opposite polarity, each of which has a period equal to that of the transmitting group recurrence interval.

The twelfth counter stage (V31) output is also fed through the twelfth amplifier, V38A, to the trace separation amplifier, V62. The trace separation amplifier uses the V38A input to produce a voltage, which positions the electron sweep beam toward the upper section of the indicator (V60) screen during the period of reception of the pulse from the master transmitter of a transmitting group. The total period of this sweep is designated the A period.

During reception of the pulse from the slave transmitter, the trace separation amplifier (V62) output causes the electron beam to be positioned toward the lower section of the indicator tube. The total period of this sweep is called the B period (fig. 11-13).

The shaper V50A, 10-kc filter, and goniometer circuit comprising V46, B1, V47, and V48 (fig. 11-12) produces a sine wave from the 10-kc, 100-us output of the third counter, V22, which is used in the fixed and variable delay circuits. The fixed and variable delay stages, in turn, combine their various inputs to produce a trigger pulse, which is coupled to the pedestal generator, V54.

The variable delay voltages from V39 through V45 are combined with the output of the clipper, V48, in the delay thyratron, V49. The fixed delay is derived by combining the output from the seventh counter, V26A, with the output of a clipper, V51, in the 1625-us gate stage, V52. Clipper V51 is driven by the 10-kc output of V50B.

Two pedestal pulses are produced by the receiving set shown in figure 11-13. One pedestal is produced during the A period, and the other during the B period. The time of occurrence of the A pedestals is fixed by the arrival of the trigger pulse from the seventh counter stage, V26.

A delay crank (fig. 11-12) controls the variable delay system so that the B output pedestal pulse is gated by the input from the twelfth counter, V31, to occur only during the B period. The B pedestal is variable from a time shortly after the reset pulse initiating the B period to the end of the available delay time incorporated in the receiving set. Both A and B pedestal pulses are coupled (during their respective periods) from the pedestal amplifier V55, to the lower vertical deflection plate of V60, and to the automatic frequency-control circuits, as discussed. The accuracy of the

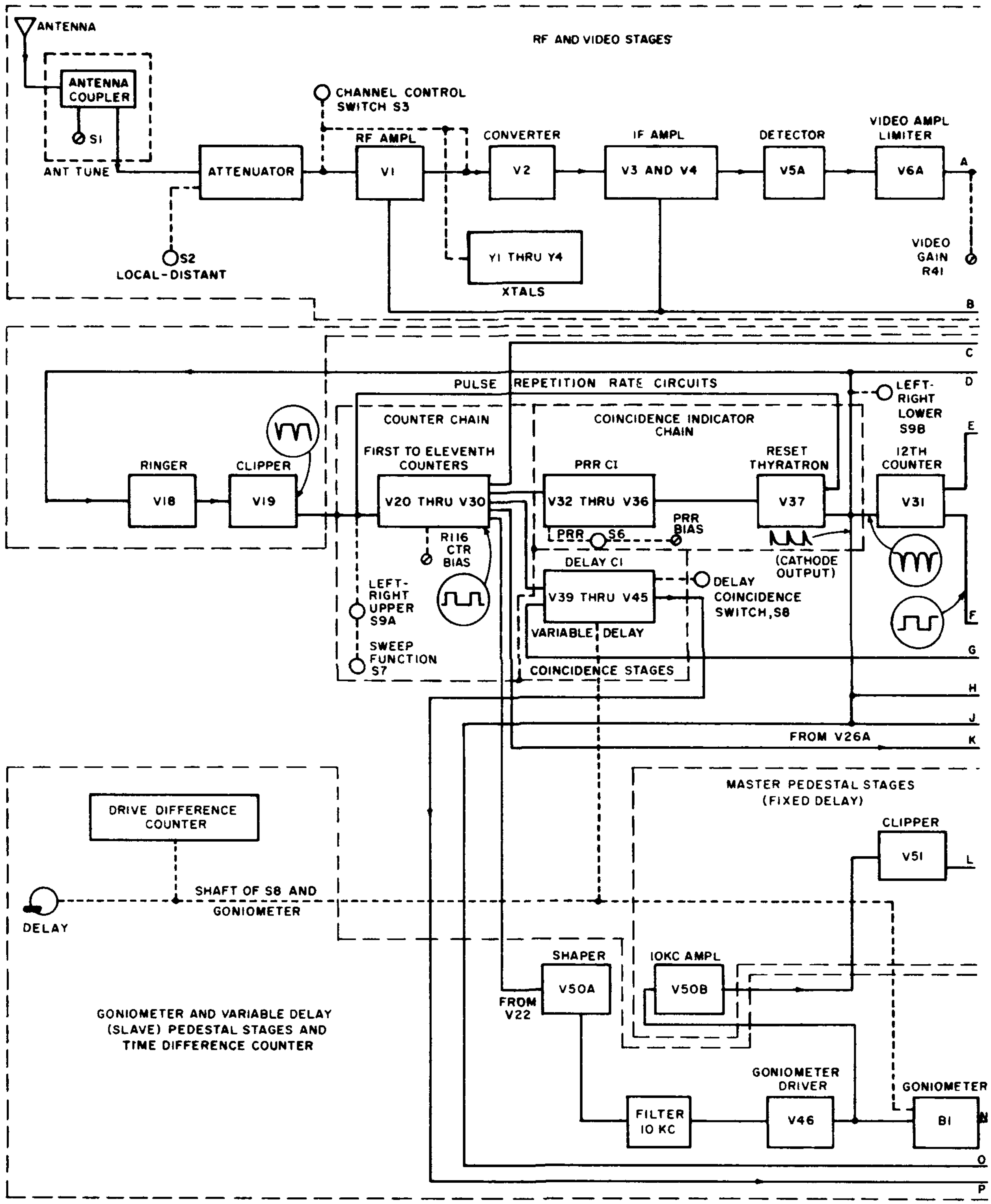

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Figure 11-12.—Loran Receiving Set AN/UPN-12, block diagram.

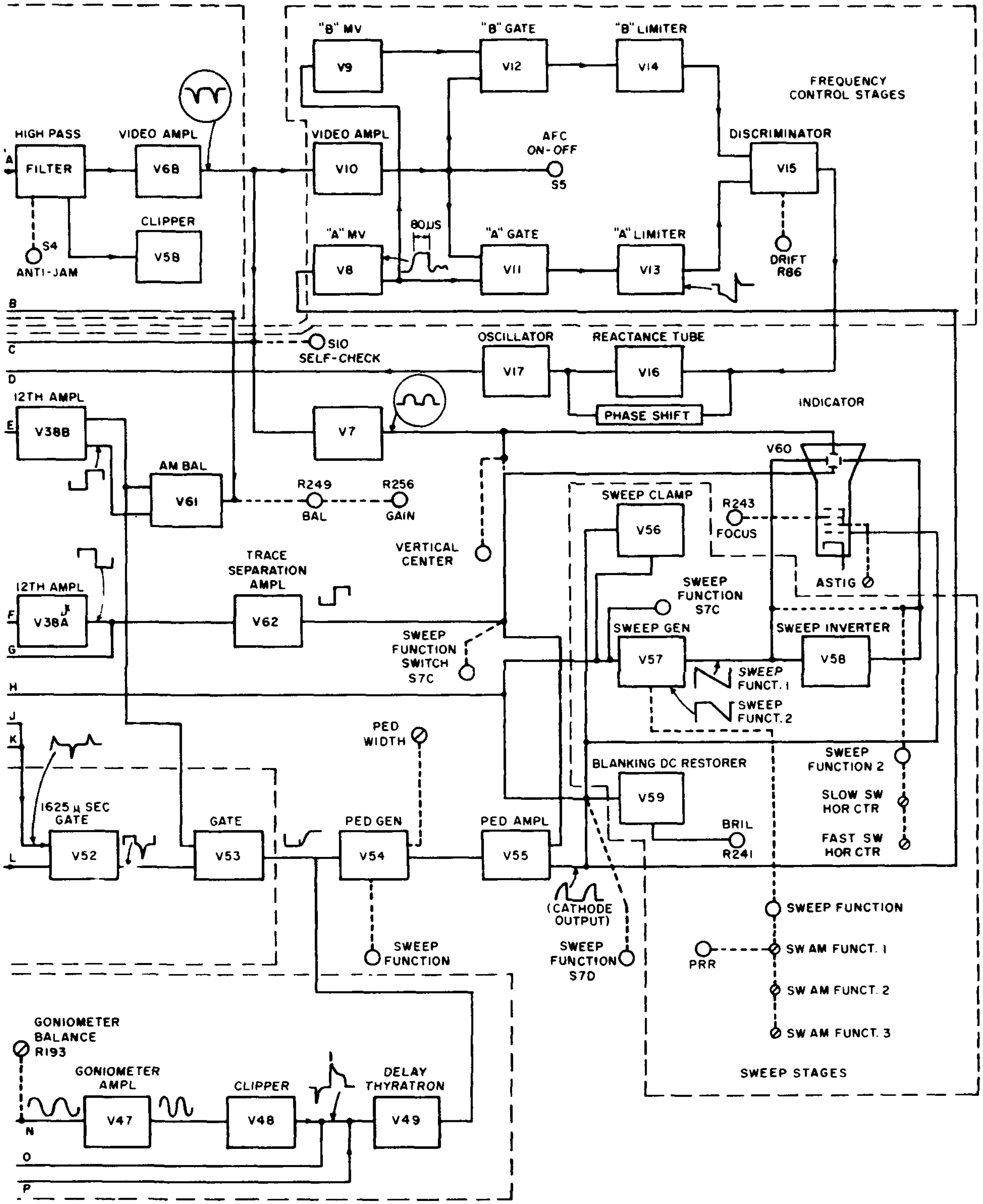

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Figure 11-12.—Loran Receiving Set AN/UPN-12, block diagram—Continued.

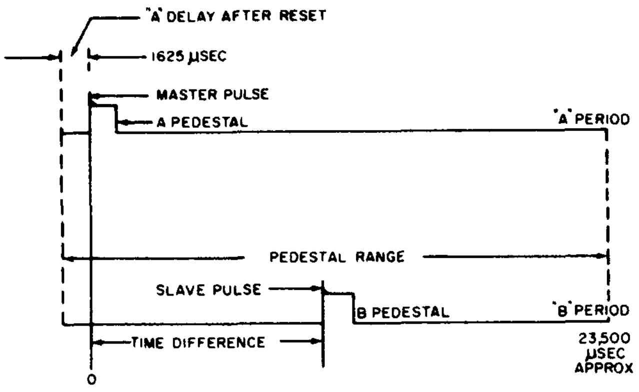

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Figure 11-13.—CRT presentation (sweep function 1 operation)

delay readings obtained depends upon the accuracy with which the master and slave pulses can be superimposed (see figure 11-14, C).

The master and slave pulses may vary considerably in amplitude. An amplitude balance circuit, V61 (fig. 11-12) whose output is adjusted by the balance and gain controls, R249 and R256, provides a means of equalizing the master and slave pulse amplitudes in the A and B periods, respectively.

The sweep stages, V56, V57, and V58, produce the push-pull horizontal sweep voltages for the indicator tube, V60. The balancing d-c restorer, V59, blanks the indicator tube during the retrace periods.

The sweep function switch (fig. 11-12) may be moved to either of three positions to determine the type of pattern presented on the indicator tube. In SWEEP FUNCTION 1 position (see figure 11-14) the pedestal pulses are displayed on the Separated A and B traces respectively. In sweep function 2, the pedestals are not used for display purposes. In sweep function 3, superimposition of the traces is accomplished for matching of the two pulses (A and B), and trace separation is not used.

Figure 11-13 depicts the waveform components on the indicator tube when the sweep function switch (fig. 11-12) is in the SWEEP FUNCTION 1 position. The leading edge of the A pedestal is formed a short time after the reset of the A period. (The resetting action is accomplished by the reset thryatron, V37, as discussed.) This period is termed "A delay

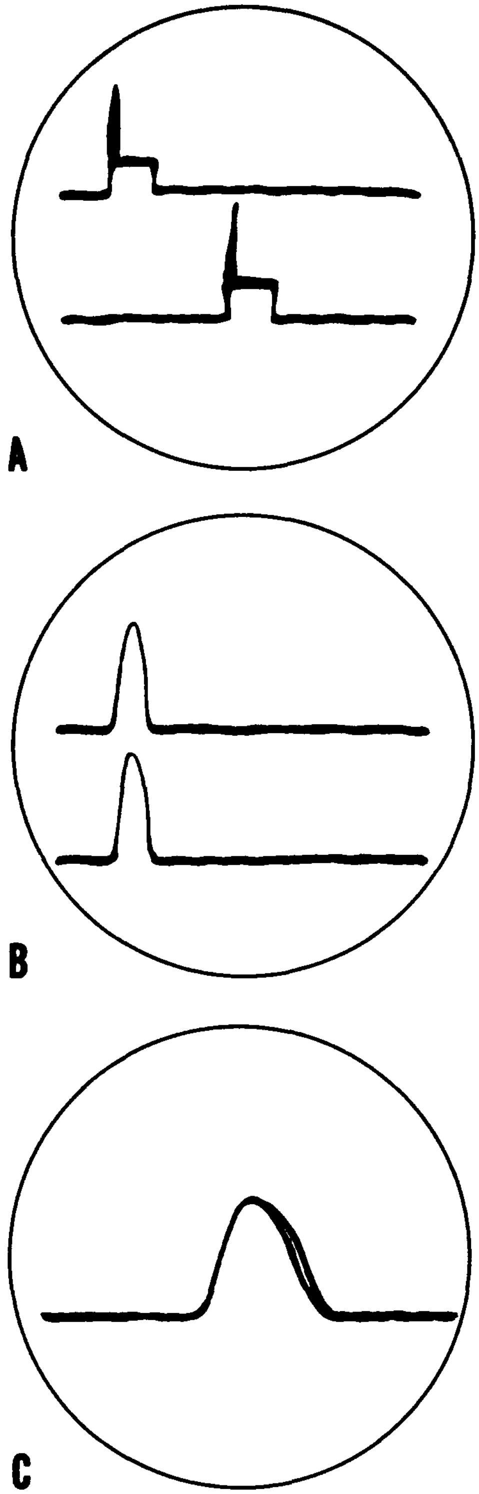

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Figure 11-14.—Cathode-ray tube presentations for sweep functions 1, 2 and 3.

after reset." The end of this period (corresponding to the time of the leading edge of the A pedestal in figure 11-13 represents zero timing on the A and B period sweeps.

As the delay crank (fig. 11-12) is rotated clockwise, the B pedestal (fig. 11-13) moves to the right, and the delay counter reading displays the time between reset of the B period and the leading edge of the slave pedestal, less the A delay. The time-difference counter reading is thus equal to the indicated time difference when the received master pulse is placed at the leading edge of the upper A pedestal, and the slave pulse is situated at the leading edge of the lower B pedestal.

In sweep function 2 (fig. 11-12) the sweep function switch, section S7D permits the pedestal amplifier, V55, pedestal output to be applied to the sweep clamp stage, V56. The V56 output, in turn, drives the sweep generator, V57. At the same time, the pedestals are removed from the indicator display by S7C, and only the signals occurring on the pedestals during sweep function 1 are displayed by the indicator, V60.

For sweep function 3 of the sweep function switch, S7, the indicator trace displays the video signals which are present during the first 160 μs (approx) of the pedestal period. The trace separation stage, V62, is disabled by S7C, and the two traces are superimposed for matching of the received pulses.

OPERATING PROCEDURES

All controls necessary for the operation of the AN/UPN-12 are located on the front panel (fig. 11-15). Below is a summary of the operating procedure to obtain a loran fix.

1. Turn the STANDBY-OFF-POWER-ON switch to the standby position; wait about one minute for the set to warm up then turn the switch to the power on position.

2. Set the ANTI-JAM switch to the out position, the SWEEP-FUNCTION switch to position 1, the AFC switch to off, and the LOCAL-DIST switch to the D (distant) position. The

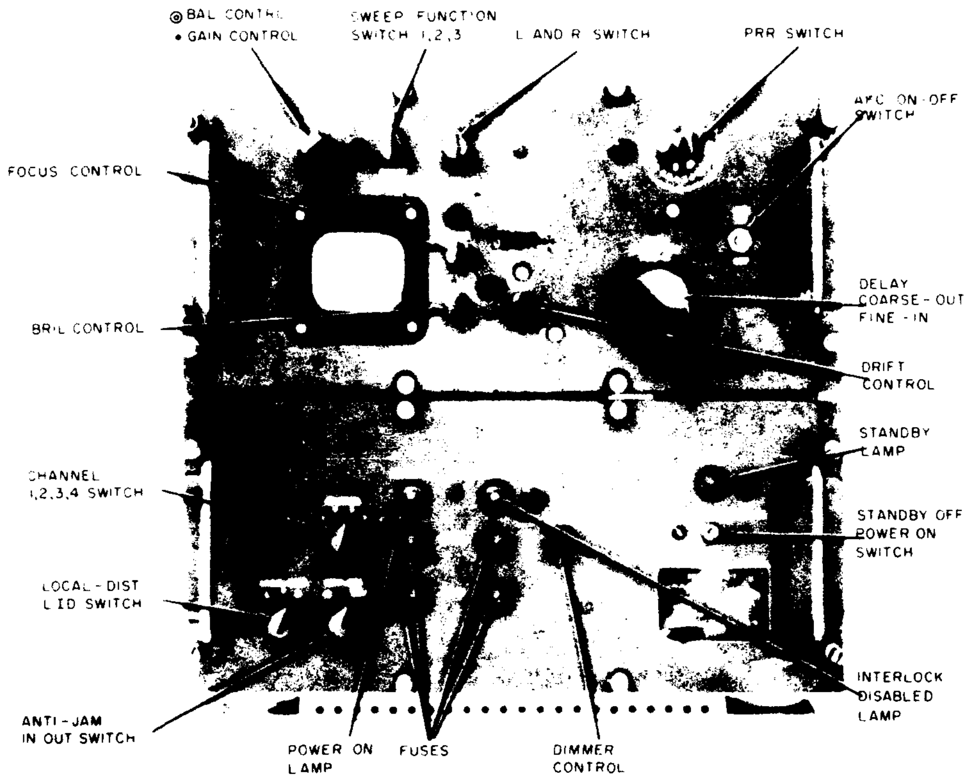

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Figure 11-15.—Front panel controls, AN/UPN-12.

ANTI-JAM switch is used in the out position unless jamming or heavy interference is experienced. The LOCAL-DIST switch is normally used in the D position for maximum sensitivity.

3. Refer to the loran charts and set the PRR (pulse recurrence rate) and CHANNEL switches to positions corresponding to one of the transmitting pairs covering the area. Set the TIME DIFFERENCE counter to 11000 with the DELAY crank.

4. Adjust the GAIN and BAL controls until the amplitude of the signals are approximately twice that of the pedestals, then stop any movement of the signals with the DRIFT control.

5. Examine the pulses and determine whether ground or sky-wave matching is to be used. Use the L-R switch to position the upper (master) pulse at the leading (left) edge of the upper pedestal, then use the DELAY crank in the coarse position to place the leading edge of the lower pedestal under the lower (slave) pulse (fig. 11-14A). Turn the AFC switch to on.

6. Set the SWEEP-FUNCTION switch to position 2 and use the DELAY crank to align the two pulses (fig. 11-14B).

7. Set the SWEEP-FUNCTION switch to position 3, and readjust the pulses with the GAIN and BAL controls, then use the DELAY crank in the fine position to superimpose the two pulses (fig. 11-14C).

8. Record the reading on the TIME-DIFFERENCE counter, and the time it was made.

9. Set the PRR and CHANNEL switches to positions corresponding to the other of the transmitting pairs and repeat steps 4 through 8 to obtain the second TIME-DIFFERENCE reading.

10. Apply the necessary corrections to the TIME-DIFFERENCE readings, plot the lines of position, and determine the loran fix.

CHAPTER 12

MAINTENANCE PROCEDURES AND TECHNIQUES, PART I

Essentially all electronic equipment can be subdivided into one or more of the following categories: (1) transmitter, (2) receiver, (3) amplifier, or (4) indicator

The function of any transmitter (radio, radar, or sonar) is to generate the carrier frequency and then to amplify, modulate, and finally to radiate it from a suitable antenna. Every transmitter must have the required ability to stay on the assigned frequency (frequency stability), to transmit faithfully the desired intelligence (fidelity), and to produce the required output power.

The function of any receiver (radio, radar, or sonar) is to receive, amplify, and deliver the desired intelligence in a useful form. Every receiver must have the required ability to pick up weak signals (receiver sensitivity), to pick up a signal at the desired frequency while rejecting signals on adjacent frequencies (receiver selectivity), and to amplify an incoming signal and deliver it to an indicator without distortion (receiver fidelity).

The function of any amplifier is to increase the strength of the signal fed to it without adding anything to the signal or removing anything from it.

The function of any type of indicator is to present information in the desired manner, without distortion.

When an electronic equipment deviates appreciably from normal operation, it will generally be noted by the operator. If the trouble cannot be corrected by operational maintenance procedures, technical maintenance (as outlined in the appropriate instruction book or technical manual) will be necessary. Technical (or corrective) maintenance procedures differ widely among the various electronic equipments, and therefore the appropriate instruction book must be used.

Besides the major units, you will be concerned also with the various accessories, such as transmission lines, antenna systems, motors, motor-generators, synchros and servomechanisms, switching systems, and others.

Also, external surfaces should be dusted periodically. Interiors of equipments should be cleaned carefully at weekly intervals with a soft brush and, if available, a vacuum cleaner.

Periodic cleaning of the interior of radio transmitters or other equipments employing high voltage is particularly important. Potentials in excess of 3000 volts are often present in these equipments, and dust on insulators or other high-voltage components forms a convenient path for arc-overs and consequent damage. In addition, a mixture of dust and lubricant forms an excellent abrasive, which can do considerable damage to moving parts.

An indication of the scope of the work done by the ET is contained in the list of the following items normally done by the ship's force (of course, not all of the jobs listed are performed by the ET 3):

1. Antennas—cleaning and painting; replacement of wire antennas.
2. Bearings—replacement in small motors and generators.
3. Cabling—replacement of short lengths not critical in nature.
4. Direction finders—cleaning, routine maintenance, loop checks, and calibration.
5. Field changes—all field changes of a minor nature and those designated as being accomplished by ship's force.
6. Generators—routine cleaning, maintenance, and minor repairs.
7. Insulators—cleaning and replacement as required.
8. Jacks (phone)—replacement and repair.
9. Keys (telegraph)—installation, replacement, adjustment, and repair.
10. Loran—repair and adjustment.
11. Meters—minor repairs only; replacement of meters that are integral parts of equipment.

12. Oscilloscopes—repair and adjustment.
13. Receivers (all types)—all tests and repairs except alignment.
14. Transmitters (all types)—all tests, repairs, and alterations except major changes and repairs to sealed oscillator compartments.
15. Test instruments—all repairs.

TYPES OF MAINTENANCE, ALTERATION, AND REPAIR

OPERATIONAL MAINTENANCE consists normally of inspection, cleaning, servicing, preservation, lubrication, and adjustment, as required, and may also consist of minor parts replacement not requiring high technical skill or internal alignment.

TECHNICAL MAINTENANCE (corrective maintenance) will normally be limited to maintenance consisting of replacement of unserviceable parts, subassemblies, or assemblies and the alignment, testing, and adjustment (internal) of equipment. (This work, in general, requires skill and detailed knowledge of equipment.)

PREVENTIVE MAINTENANCE is the systematic accomplishment of items deemed necessary to reduce or eliminate failures and prolong the useful life of the equipment. (These items are more specifically defined and outlined in the instruction books and POMSEE books (if applicable) furnished with each equipment. This work, in general, requires skill and a detailed knowledge of the equipment.)

TENDER/YARD MAINTENANCE requires a major overhaul or complete rebuilding of parts, subassemblies, or the end items, as required.

A ship may not informally, on her own, come alongside a repair ship or tender or enter a naval shipyard for repairs. The control and disposition of a ship is at all times a function of certain operating commands. Thus when a ship needs outside repair, the type commander, or higher authority, assigns the ship an "availability" at a repair activity. The term "availability" is defined by Navy regulations as the period of time assigned a ship by competent authority for the uninterrupted accomplishment of work at a repair activity. The three major types of availabilities are regular overhaul, restricted, and technical.

REGULAR OVERHAUL.—A regular overhaul availability is for the accomplishment of general repairs at a naval shipyard or other shore-based repair activity. The length and interval between regular overhauls vary for different type ships and are established upon recommendations by the fleet and type commanders.

RESTRICTED AVAILABILITY.—This availability is assigned by the type commander for the accomplishment of specific work by a shore-based repair activity such as a naval shipyard or ship repair facility. The conditions for which restricted availabilities may be granted include:

1. Post-shakedown repairs in the case of new construction, conversions, or recommissioned vessels.
2. Repairs which should be undertaken to ensure safe and reliable operation, prevent deterioration, ensure health and comfort of crew, or to permit a vessel to maintain scheduled operations.
3. Urgent military alterations.

The rules governing the preparation of the shipyard work list for a restricted availability are the same as those for regular overhaul except that the work requested is restricted to the specific items for which availability has been granted. No readiness-for-sea period is included for a restricted availability unless assigned specifically by the type commander.

TECHNICAL AVAILABILITY.—A technical availability is assigned to a shipyard or equivalent shore-based repair activity for work with the vessel not physically present. Technical availabilities are assigned by the type commander. Under certain circumstances, however, technical availability may be granted by the operational commander.

The most common type of technical availability repair involves shop work only. Frequently, however, technical availabilities are used when the ship is in the same port, or very near the shore-based repair facility, as a device for authorizing the sending of technical personnel aboard for inspection of trouble or to give advice; or if large numbers of workmen are not involved, for repairs as well. Technical availability should not be requested unless the repair needed is beyond the capacity of forces afloat; i.e., ships' forces and available tender and repair ships.

The procedures for submitting a request for technical availability are set forth by type commanders in appropriate type instructions.

Maintenance work accomplished on all shipboard machinery and equipment may be grouped into three general categories: (1) repairs, (2) alterations, and (3) alterations equivalent to repairs.

REPAIR is defined as the work necessary to restore a ship or article to serviceable condition without change in design, materials, number, location, or relationship of the component parts. Repair work items are determined by the ship's force. Major items are approved for accomplishment by the ship's commanding officer if the work can be accomplished by the ship's force, or the type commander concerned if the work cannot be accomplished by the ship's force.

ALTERATION is defined as any change in the hull, machinery, equipment, or fittings that involves a change in design, materials, number, location, or which involves a change in the relationship of the component parts of an assembly regardless of whether any such change is undertaken separately from, incidental to, or in conjunction with repairs.

Requests for alterations may originate from the technical bureaus, from the forces afloat, or from the Chief of Naval Operations. In any case the technical bureau having cognizance of the equipment concerned approves the alteration provided the alteration does not affect the military characteristics of the ship. Alterations under the technical cognizance of BuShips are referred to as ShipAlts. Alterations affecting the military characteristics of a ship are referred to as NavAlts, and must be approved by the Chief of Naval Operations.

ALTERATIONS EQUIVALENT TO REPAIRS.—An alteration is considered equivalent to a repair when any of the following conditions exist:

1. It involves the use of different materials from standard stock, which have been approved for similar use.
2. Worn or damaged parts requiring replacement are replaced by those of later and more efficient design previously approved by the bureau concerned.
3. The alteration consists of strengthening of parts which require repair or replacement, to improve the reliability of the parts and of the unit, but no other change in design is involved.
4. Minor modifications are made that involve no significant changes in design or functioning of equipment, but are considered essential to prevent reoccurrence of unsatisfactory conditions.

Alterations equivalent to repairs may be approved and authorized by type commanders without reference to the bureau concerned when they do not involve increase in weight or vertical moment. They are financed and administered in the same manner as repairs, except that their completion is reported to the bureau concerned.

FIELD CHANGE is any modification or alteration made to an electronic equipment subsequent to delivery to the government and authorized by the bureau or agency concerned.

MAINTENANCE BEYOND THE CAPACITY OF SHIP OR STATION FORCES is performed by tender or naval shipyards and industrial managers or by contractors or other agencies responsible to the maintenance yard.

Although there may be certain exceptions, operational maintenance is done by the operational ratings and technical maintenance (corrective maintenance) is done by the technical ratings. The duties of the two ratings are summarized as follows:

1. Operational ratings—operational use, manipulation, and operational maintenance of electronic equipment associated with the technical specialties of the ratings and such portions of preventive maintenance as do not require realignment after accomplishment.
2. Technical ratings—manipulation, technical and tender/yard maintenance, repair of electronic equipment and preventive maintenance, which requires realignment after accomplishment.

As has been stated, the operational maintenance and much of the preventive maintenance should be done by the operating personnel. This includes daily checks on the operating controls to note binding, excessive play, or other defects. Meter readings should be checked daily to determine if they are normal (the exact procedures are outlined in the appropriate Maintenance Standards Book described later). Equipments should also be checked daily for loose knobs, burned out pilot lights, loose cable couplings or bonding straps, missing spare fuses, and broken meter glasses.

PREVENTIVE MAINTENANCE PROCEDURES

In this portion of the chapter some of the more common preventive maintenance

procedures are discussed briefly. It is obvious that the way the operator or the technician goes about his preventive maintenance duties depends upon the type of equipment (or equipments) to which he is assigned. In any case, the steps to be followed in performing preventive maintenance is spelled out in detail in the equipment instruction book. Generally, one section of the instruction book is devoted entirely to preventive maintenance. However, in the new specifications, preventive maintenance will be included in the operator's volume or in the POMSEE books.

Certain items like cleaning and lubricating electronic equipment, maintaining air filters, caring for motors and motor-generators, and testing electron tubes and crystal diodes are sufficiently general to be treated under separate headings. However, preventive maintenance, as applied to specific equipments, must conform to the specific routine spelled out in the Maintenance Standards Book or the equipment instruction book. To illustrate the methods commonly used in maintaining the various types of electronic equipments, a brief summary of the preventive maintenance procedure for certain typical equipments is included. For the detailed procedure, the equipment instruction book must be consulted in each case.

THE POMSEE PROGRAM

The Bureau of Ships is supplementing existing instruction books or technical manuals with two separate publications which together make up the POMSEE program. The expression, POMSEE, means "Performance, Operational, and Maintenance Standards for Electronic Equipment." The POMSEE publications are described as follows:

1. Performance Standards Sheets provide the operational performance data and basic technical measurements indicative of the minimum acceptable level of performance for electronic equipment. A binder, titled "Binder for Electronic Equipment Performance Standard Sheets (NavShips 93000)," for incorporating all sheets required on a ship under one cover, has been distributed.

2. Maintenance Standards Books provide standard methods for determining measurements affecting the performance of a specific equipment, space to record such measurements, and a preventive maintenance schedule for the equipment. The Maintenance Standards Book includes Part I, Test Procedures and Maintenance References and Part II, Preventive Maintenance Check-Off.

The Maintenance Standards Book, Part I, Test Procedures and Maintenance References provides an itemized step-by-step procedure, which enables the engineer or other person making the standard tests to set down critical or significant operating values (dial readings, etc.) representative of optimum operating conditions. Upper and lower limits or tolerances for dial readings, voltages, or currents are given so that an indication is readily available if performance is below the allowable limits. No attempt is made to show how to locate the trouble; however, a comparison with established critical circuit readings will help the ET to isolate the trouble.

Reference to the instruction book for the particular equipment is still required for troubleshooting or corrective maintenance.

The Maintenance Standards Book, Part II, Preventive Maintenance Check-Off requires that standard tests be performed at regular intervals on circuits and components and specifies what and when other routine maintenance, such as lubrication, is to be accomplished. By the proper use of this book, routine checks and routine preventive maintenance may be accomplished in a systematic manner.

In general, the same steps required for determining the standards in Part I must be repeated later by the ship's force in making routine checks for entry in Part II.

The daily and some of the weekly tests prescribed should be done by operators, not technicians, so that the ETs can concentrate on corrective maintenance. The Electronics Material Officer will determine who should undertake the routine tests.

TOOLS

Most faults in an electronic assembly cannot be prevented or corrected without the use of tools. Therefore, the first step in preparing to check out transistors or other semiconductors, tubes, printed circuits, etc., is the acquisition of the proper tools. The ease with which a check or repair can be made is often a direct function of the adequacy of the tool selected to perform the given task.

In the performance of their duties, maintenance personnel should be provided with, or have access to, at least one each of the basic

tools listed in the Electronics Tool Allowance List. In general, the number and types of tools required are determined by the types of nuts, bolts, screws, fasteners, etc., employed in the equipment being serviced.

Since transistors and other components and equipments are extremely small, conventional-size tools frequently are unsuitable for effective use; the technician requires tools which, because of their greatly reduced size, are better able to cope with the limited space encountered in compact, miniaturized equipment. In addition, special devices which extend the vision, aid the reach, and sometimes act as a third hand are required in servicing or repairing the equipment. Figure 12-1 shows a few such special devices which are discussed below.

A suitable and easily fabricated device that fits into this category is the chassis-holding jig described in chapter 13 of this training course. This jig will provide support for the electronic assembly when the assembly is removed from its regular mounting for checking or repair. It will also prevent flexing or slipping which could result in unnecessary damage.

A portable drawer can be fabricated by attaching a piece of sailcloth or old white sheet to the inside of the drawer. Attaching the above jig, or similar chassis-holding jig, onto the side of the drawer and over the cloth area will prevent the loss of any tiny part that may be accidentally dropped. In attaching the cloth to the inside of the drawer, leave a small amount of slack so that it will sag in the middle; thus, if a part should be accidentally dropped, it can be easily located by gently tapping the cloth. The part will then find its way to the middle.

A portable lamp (fluorescent if approved for use in the work area) is a very desirable light source for small work in spaces which are inadequately lighted. The swivel clamp arrangement on the base of the lamp fixture can be secured to the work area or side of the equipment frame, allowing both hands to be free. This lamp is preferable to a flashlight for lengthy repairs.

In many instances, breaks in the conducting strips (foil) of a printed-wiring circuit board can be located only with the aid of a magnifying glass or device. In this case a magnifying glass or device should be kept handy for such use.

A pin vise is a very useful tool for drilling through thin plastic, bakelite, or copper-ribbon conductor strips. The pin vise also will hold various sizes and shapes of hooks and probes

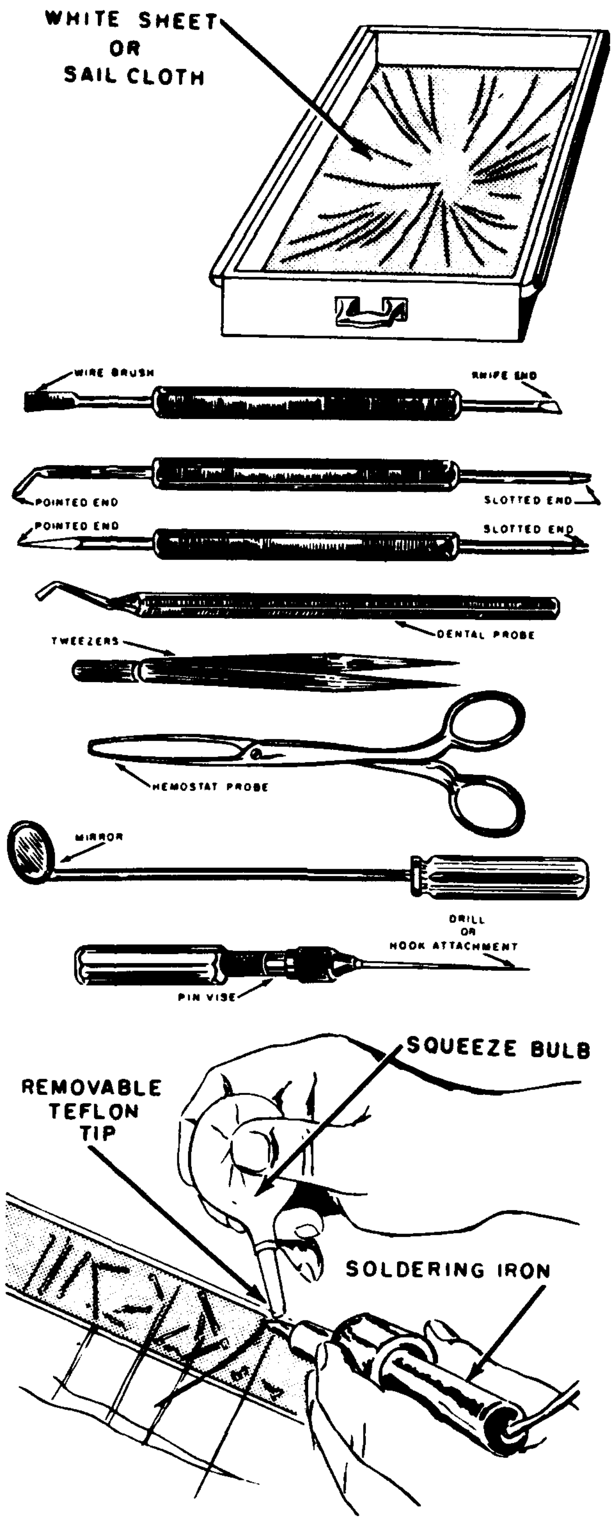

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Figure 12-1.—Special devices.

fabricated from spring wire, for extracting or holding small parts in limited spaces.

Many advantages also can be gained by the use of offset screwdrivers and tools which decrease the area of space required for turning action.

Surgical hemostats, tweezers, hypodermic syringes, and surgical needles are available in many types and shapes, and sizes; these implements are ideally suited for reaching into tight places, for retrieving or holding small parts, and for oiling hard-to-reach lubrication points. The surgical hemostats or tweezers also may be used as thermal shunts to dissipate heat away from heat-sensitive semiconductor devices; however, this method of application is only partially satisfactory.

Many of the special tools used by the dental and medical department can be easily adapted for use in servicing electronic equipment. They may have several special tools on hand which are no longer suitable for their work, but which would be ideally suited as labor-saving devices for the electronics technician.

The most important requirement in the checking, servicing, and repair of electronic equipment is the use of a light-duty pencil soldering iron with an assortment of interchangeable tips and soldering aids, as shown in chapter 13 of this training course.

Another very useful tool is a 1-ounce rubber syringe with a special removable Teflon Tip, such as the device manufactured by the MacDonald Company. This tool is very useful in sucking up excess solder and flux; when properly used, this device will eliminate smearing of solder over the rest of the board being repaired. It can be used as a bellows to dissipate excessive concentrated heat.

In summary, special tool requirements depend on the maintenance operations and the design characteristics of the equipment to be checked, serviced, or repaired. An adequate assortment of special tools (aids) is necessary in checking and in solving certain maintenance problems associated with present day electronic assemblies. However, the number of special tools should be held to a minimum compatible with actual equipment needs.

SAFETY PRACTICES

Safety is a major responsibility of all personnel working on or around electronics. The installation, maintenance, and operation of electronic equipment requires a stern safety code. Carelessness on the part of the electronics technician or operator can result in serious injury or death due to electrical shock, falls, burns, flying objects, etc.

After an accident has happened, investigation generally shows that it could have been prevented if simple safety precautions and procedures had been observed. Each man concerned with electronic equipment should make it his responsibility to read and become thoroughly familiar with the safety practices and procedures contained in U. S. Navy Safety Practices (OPNAV-34P1), chapter 67 of BUSHIPS Technical Manual (NAVSHIPS 250 000), NAVMEDS publication (P5056), technical manuals, schematics, wiring diagrams, etc., before performing work on electronic equipment. It is your responsibility as an electronics repairman or operator to identify and eliminate unsafe conditions and unsafe acts which cause accidents.

In pursuit of this responsibility, it must be borne in mind that deenergizing main supply circuits by opening supply switches, circuit breakers, or circuit switches will not necessarily KILL all circuits in a given piece of equipment. A source of danger that often has been neglected or ignored—sometimes with tragic results—is the inputs to electronic equipment from other sources, such as synchros, remote control circuits, etc. For example, turning off the antenna safety switch will disable the antenna, but it may not turn off the antenna synchro voltages from the ship's compass or stable elements. Moreover, the rescue of a victim shocked by the power input from a remote source often is hampered because of the time required to determine the source of power and turn it off.

NOTE: TURN OFF ALL POWER INPUTS BEFORE WORKING ON EQUIPMENT.

Hazards associated with the use of electrical power tools are electrical shock, cuts, bruises, falls, particles in the eye, explosions, etc. Safe practice in the use of these tools will reduce or eliminate such accidents. Personnel also should be aware that the removal of a unit or part from its normal location for servicing also will remove the protection given by built-in safety features.

Do NOT troubleshoot a circuit with the primary power applied, unless absolutely necessary. If it becomes necessary to work on equipment with the power applied, stand on a good insulating material keeping one hand free

at all times—BEHIND YOU OR IN YOUR POCKET.

Most of the hazards which will confront you in electronics maintenance and repair will be associated with careless maintenance practices. Remember that the 115-volt power supply voltage is not a low, relatively harmless voltage (only voltages below 30 volts are in this class), but it is the most lethal voltage used in the Navy. More accidents happen with this voltage than with any other because many sailors consider such a voltage relatively harmless and disregard safety measures. When we think of electrocution, we are inclined to think in terms of high voltages, but a point always to remember is that MORE PEOPLE ARE KILLED BY 115-VOLTS THAN ANY OTHER VOLTAGE.

There are two types of injuries resulting from an accident which may require first aid immediately to save a life. In the case of severe electrical shock, the victim's system may be paralyzed; in such a case immediate artificial respiration is necessary to save the victim's life. When working with tools and equipment, it always is possible that you or someone else may receive a wound from which there is excessive or dangerous bleeding. In such a case, knowledge of how to control the flow of blood may mean the difference between life and death for you or a fellow worker. Standard first aid procedures are given in the Blue Jackets Manual and the Standard First Aid Training Course, NavPers 10081. Standard first aid measures have remained basically unchanged from those you learned as a boy scout. One of the changes is the artificial respiration methods which has progressed to mouth-to-mouth resuscitation. Important references are given in chapter 2 of this training course. These references are excellent for first aid familiarization and each man concerned with electronic equipment should make it his responsibility to understand and practice all prescribed safety precautions. REMEMBER: WORK SAFE AND BE SAFE. DON'T DAMAGE THE EQUIPMENT AND DON'T LET THE EQUIPMENT DAMAGE YOU.

CLEANING PRACTICES

The successful restoration and reconditioning of electronic equipment, especially equipment that has been subjected to contamination from foreign materials such as dust, soil, and salt water, require that the electronics technician have not only a thorough knowledge of cleaning materials, but also that he select cleaning equipment and chemicals which perform properly together to produce the desired results of cleanliness with the minimum amount of disassembly.

There are a number of cleaning solvents, compounds, and materials listed in the Navy Stock List. Although many of these items are excellent, may others have serious limitations concerning their safe use and application. Their factors include possible harmful effects on the material being cleaned, storage qualities, safety in use (flammable, toxic, or both), and relative cost. Therefore, sound judgment must be exercised by maintenance personnel in the selection of the cleaning materials used to meet the different cleaning requirements encountered, before a cleaning solvent, compound, or method of application is judged as being suitable for use.

Dirt, dust, and other foreign materials form on surfaces where they are not wanted, and thus contaminate the surfaces. For this reason, in order to maintain any equipment in the best operating condition, a scheduled cleaning program of periodic maintenance to suit the particular operating schedule in effect should be established and followed.

The cleaning of equipment which is contaminated with loose, dry dust or dirt particles or with oils, grease, etc., should be accomplished as follows:

ACCESSIBLE SURFACES.—Use a clean, dry, lint-free wiping cloth or rag, or a bristle brush moistened with a cleaning solvent.

INACCESSIBLE SURFACES.—Remove the covers and protective devices on the equipment being cleaned; attach an air hose to a dry, filtered air outlet that is regulated at less than 50 psi pressure and blow the dust or dirt particles from the contaminated surface area, or spray a cleaning solvent, with an air gun, onto the contaminated surfaces.

CAUTION: Exercise extreme care when using compressed air on delicate parts. Protective equipment (goggles, rubber gloves, protective clothing, fire extinguishers, etc.) must be provided for personnel using solvent for cleaning purposes. Ensure adequate ventilation by using exhaust fans or supply blowers. NEVER WORK ALONE.

In extreme cases, where electronic equipment has been subjected to salt water flooding

or to excessive condensation from humid, salt-laden air, fresh water (preferably warm or hot) can be used to flush out the contamination. However, the use of fresh water is recommended only as an emergency substitute for a cleaning solvent, since it must be followed by a thorough drying process before the equipment can be restored to service.

In many cases, equipment flooding is accompanied by organic contamination resulting from damaged fuel lines or flooded gear boxes, etc. In such cases the viscous, adherent oil resists removal by water, but a cleaning emulsion formulation (see EIB 593) will remove most oily contaminants and sea water at the same time.

Solvents may be mixed with soaps, synthetic detergents, alkalies, and water to formulate other cleaning emulsions that will remove sea water and oil contamination from the affected parts. A wetting agent added to the cleaning solution may also increase its cleaning capabilities.

When using an emulsion cleaner, all exterior and interior contaminated surfaces should be sprayed with the emulsion, after which the surfaces should be flushed thoroughly with fresh water. After most of the oily contamination has been removed by the flushing process, the last traces of contamination and sea water can be removed by subjecting the equipment to ultrasonic radiation while it is immersed in the cleaning emulsion. This process is described in detail in EIB 593.

The following information was obtained from Chapter 67 of the Bureau of Ships Technical Manual.

1. All electronic equipment must be cleaned to assure good performance and not for appearance only.
2. Steel wool or emery in any form must not be used on or near electronic equipment.
3. Sandpaper and files will be used only with competent advice or not at all.
4. The use of a vacuum cleaner with NON-METALLIC hose and adequate dust receiver is to be resorted to wherever practicable.
5. The use of solvents is to be resorted to only where absolutely necessary and where the proper safety precautions are taken.

Alcohol or other flammable solvents must not be used on energized equipment or on equipment near other electronic equipment from which a spark is possible. They are to be exposed in the smallest possible quantity and may be used only in well-ventilated compartments. Except in locations wholly in the open, alcohol will be limited in quantity to one pint.

For additional safety precautions that the ET must observe in cleaning electronic equipment, see United States Navy Safety Precautions, OpNav 34P1.

MAINTAINING AIR FILTERS

The maintenance of air filters is EXCEEDINGLY important for the proper operation of electronic equipment. The lack of proper servicing (cleaning or replacing) of air filters will cause an enormous amount of trouble. For some reason (perhaps they are difficult to locate or their importance is not fully recognized) it appears that air filters are often neglected or disregarded until excessive heating causes a breakdown of the equipment.

Equipments that use a great deal of power and/or have high ambient temperature must be cooled. Air cooling is commonly employed, and this means moving a large volume of air over the hot portions of the equipment. The air is filtered to keep dust and other foreign particles out of the equipment. If the filters are efficient, they will remove most of this foreign material from the air that passes through them. This foreign material will tend to clog the filter and prevent the air from moving through. The result is that the equipment gets too hot and may be ruined. AIR FILTERS MUST BE SERVICED OFTEN.

An analysis of the failures of parts in electronic equipment indicates that the MAJORITY OF FAILURES CAN BE TRACED TO EXCESSIVE HEAT CAUSED BY DIRTY AIR FILTERS. This fact cannot be overemphasized; and on the basis of this alone, it would appear that the technician can reduce his workload substantially by ensuring that air filters are properly serviced.

LUBRICATING ELECTRONIC EQUIPMENT

In electronic gear, lubrication is as important as it is anywhere else, and the carrying out of the lubrication procedure is no more complicated than in other equipments. There are actually only a few types of parts that have to be lubricated. They are summarized in a general way as follows:

1. Drive motors and motor-generator sets run at high speeds and, if not lubricated properly at regular intervals, will quickly deteriorate

and fail. Determine where the motor-generators (as well as the drive motor) are located so that they will not be overlooked during routine lubrication.

2. A radar antenna is rather slow-moving and a great deal of trouble and expense has resulted from a lack of proper lubrication. In one instance the failure to use thirty cents worth of grease resulted in a $30,000 repair bill. Several factors combine to cause antenna trouble. First, the antenna is a long way up in the air, and it is a nuisance to climb all the way up the mast to lubricate it. Second, the ship spends much of its time at sea, and the mast is no place to be when the ship is heaving around underneath. Third, the rolling and pitching of the ship throws a heavy strain on the moving parts of the pedestal, and even though the antenna moves slowly, the great pressure on the moving parts causes rapid wear unless they are kept well lubricated. Fourth, the pedestal is constantly exposed to the action of salt air and salt water, which attacks the lubricant and tends to make it less slippery.

If the antenna is neglected and the pedestal freezes, the drive motor will burn up, and the radar will be out of commission. This condition involves lifting the antenna off with a crane and results in an expensive repair job. This waste of money and time, and the possible placing of the ship in jeopardy, can be prevented if the correct lubrication procedure (as outlined in the instruction book, the lubrication charts, or POMSEE books) is followed.

There are three common methods of lubricating electronic equipment.

The first is the use of the oil can. A drop of oil from the spout of the can into the oil hole on the machinery is all that is necessary. However, there are many types of oil and you must be sure that you are using the correct one. In many cases, the mixing of dissimilar oils will form a gummy substance that has little or no lubrication properties. The result may be a frozen bearing.

The second is the use of a grease gun on a pressure-type fitting. The main thing to remember is that the fitting must be clear of dirt or paint obstructions, otherwise the grease cannot enter. Even if the grease should be forced in, dirt will be taken along and eventually the bearing will be damaged. Grease fittings should always be kept as clean as bright work; and the hole should be cleaned out with a pin before the grease gun is applied.

The third is the use of the grease cup. Grease cups are generally found on the heavier motors and motor-generators, and must be used properly if damage to the machinery is to be prevented. Information on the use of grease cups is included in the section on the care of motors and motor-generators.

For certain types of electronic equipment, special lubrication charts are provided. For example, a set of twelve plastic lubrication charts, 0280-114-4000, are provided for the personnel who lubricate the antenna of Radar Set AN/SPS-8. Pictures and instructions are given to ensure adequate lubrication instructions.

CARE OF MOTORS AND MOTOR-GENERATOR

The following information on the care of motors and generators (or motor-generators) is condensed largely from Chapter 60 of the Bureau of Ships Technical Manual. The essential points to remember are: (1) keep the insulation clean and dry and of high resistance, (2) keep the electrical connections tight, and (3) keep the machines in good mechanical condition by proper cleaning, lubrication, and replacement of defective parts.

The ET 3 is expected to be able to inspect and clean commutators and collector ring (slip ring) assemblies and inspect and replace brushes on motors and motor-generators that are used with or are a part of electronic equipment. It is therefore important that he follow the approved procedures.

The four acceptable methods of cleaning motors and generators are wiping, use of suction, use of compressed air, and use of a solvent.

LUBRICATING MOTORS AND MOTOR-GENERATORS. — The ET 3 should be familiar with and be able to distinguish between grease-lubricated and permanently lubricated ball bearings.

The grease-lubricated type requires periodic lubrication with grease. The permanently lubricated type contains two seals, has been lubricated by the manufacturer, and requires no additional lubrication throughout its life. Equipment furnished with these bearings can be recognized by the absence of grease fittings or provision for attaching grease fittings. When permanently lubricated bearings become inoperative they should be replaced with new bearings of the same type.

Cleanliness is of prime importance in avoiding ball bearing failure. Due to the extremely high pressures and close fit between balls and races, even minute particles of dust may cause bearing failure. Dirt may be introduced into the bearing housing by careless handling, or by inclusion with the lubricant, or it may work its way into the housing along the shaft.

Extreme care must be exercised in the handling of bearings, grease fittings, housing parts, and tools used in maintaining the bearings to ensure the exclusion of all foreign matter, particularly when reassembling grease fittings, etc.

Improper greasing procedures are a frequent cause of trouble in rotating electrical machinery provided with grease-lubricated ball bearings. The trouble is generally caused by an excessive quantity of grease being forced into the bearing housing. When grease is forced through the bearing seals and into the windings (or onto the commutator), deterioration of the insulation is a likely result. Excessive grease in the bearing housing itself results in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The stock numbers of grease to be used for lubricating ball bearings that operate in two broad temperature ranges are given in Chapter 60, of the Bureau of Ships Technical Manual. Machines that require the special high-temperature silicone grease have a plate with the words, USE HIGH TEMPERATURE GREASE, attached near the grease fitting.

Motors and generators provided with bearings that should be lubricated with grease are normally delivered with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole that remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel.

Care should be taken to make sure that a grease cup is clean before it is used to add grease to a bearing and that the pipe plug used to replace the grease cup after greasing is also clean.

To avoid the difficulties caused by an excessive amount of grease, grease should be added only when necessary; and, when grease is added, it should be done as follows:

1. Wipe outside of grease fitting and drain (relief) plug free of all dirt.
2. Remove bearing drain plug, and make sure the passage is open by probing with a clean screwdriver or other suitable instrument.
3. Remove pipe plug at top of grease pipe. Select the proper grease cup and clean it (top and bottom parts) thoroughly. Install the bottom portion of the grease cup on the grease pipe.
4. Fill the bottom part (receptacle) of the grease cup with clean grease.
5. Put into the top part (the part that is to be screwed down) of the grease cup no more grease than will half fill it.
6. Screw the top part of the grease cup down as far as it will go. The purpose of screwing the grease cup down is to protect the machine from being overgreased because of accidental or unauthorized turning of the top part of the grease cup.
7. Run the machine and let the grease run out of the drain hole until drainage stops (normally about 30 minutes). Remove grease cup and replace the pipe plug and the drain plug.
8. Do not use a grease gun to lubricate bearings unless there are no other means available. If a grease gun must be used, the drain plug must be removed while greasing is being done and extreme care must be used to avoid inserting too much grease.

BRUSHES.—The correct grade of brushes and correct brush adjustment are necessary to avoid commutation trouble. For good commutation:

1. Use the grade of brushes recommended by the manufacturer.
2. The brush shunts or "pigtails" should be securely connected to the brushes and the brush holder.
3. Brushes should move freely but should not be loose enough to vibrate in the holders.
4. Brushes that are half worn, or that have chipped corners or edges, should be replaced after all dirt is cleaned from the brush holders.
5. The spring tension on the brushes should be maintained according to the manufacturers' instructions (see BuShips Technical Manual, section 60-293, for details).

6. All brush holders should be the same distance from the commutator—not more than one eighth of an inch, or less than one sixteenth of an inch.

7. The toes (forward edge in the direction of rotation) of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

8. The brushes should be evenly spaced around the commutator.

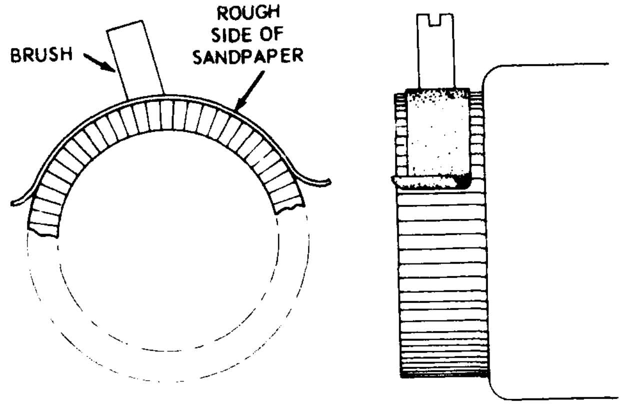
9. Brushes should be staggered in pairs (see Article 60-293 in BuShips Technical Manual) to prevent grooving of the commutator.

10. The brush surface in contact with the commutator should be an accurate fit.

When new brushes are installed, or old brushes do not fit, they should be fitted and seated. For this purpose, sandpaper and/or a brush seater should be used. Sandpaper is probably more familiar to everyone, but the use of a brush seater has certain advantages. (Never use emery paper or any other kind of paper or cloth containing a metallic abrasive.)

When using sandpaper to fit brushes, disconnect all power and make sure the machine cannot be started while the work is being done. Lift the brushes to be sanded and insert a strip of fine sandpaper (No. 1) sand side up, between the brushes and the commutator. With the sandpaper held tightly against the commutator surface (to conform to the curvature), and the brushes held down by normal spring pressure, the sandpaper is pulled in the direction of normal rotation of the machine (see fig. 12-2). When the sandpaper is reinserted for another pull, the brushes must be lifted. This operation is repeated until the fit of the brush is accurate. Always finish with a finer grade (No. 0) sandpaper. Use a vacuum to remove the dust during the sanding operation; afterwards, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

The brush seater consists of a mildly abrasive material loosely bonded and formed in the shape of a stick about five inches in length. The brush seater is applied to the commutator while the machine is running, and therefore every precaution must be taken to prevent injury to the person applying it. The brush seater is applied lightly, for a second or two, exactly at the heel of each brush (fig. 12-3). If the seater is placed even one-fourth inch away from the heel of the brush, only a small part of the abrasive will pass under the brush. Pressure is applied to the brush by setting the brush



1.52
Figure 12-2.—Method of sanding brushes.

spring tension at maximum (during the seating operation) or by pressing a stick of insulating material against the brush. Dust is removed during the operation, and the machine is thoroughly cleaned afterwards the same way as when sandpaper is used.

COMMUTATORS AND COLLECTOR RINGS. —In a properly operating machine, the commutator will develop (within about two weeks of use) a uniform, glazed, dark brown polish where the brushes ride on it. A nonuniform color or surface or a bluish color indicates improper

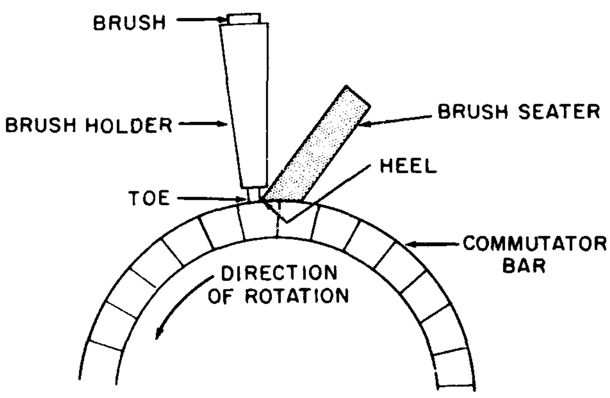


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Figure 12-3.—Using the brush seater.

commutation conditions. If the commutator retains a smooth, uniform finish of the proper color and shows no evidence of poor commutation, it may be cleaned with a canvas wiper, as described in the following paragraph. If however, the commutator cannot be sufficiently cleaned with the canvas wiper, or if the surface is slightly rough, a fine grade of sandpaper may be needed. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.

One of the most effective ways of cleaning commutators or collector rings is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong, pliable wood strip and securing the canvas with rivets, as shown in figure 12-4A. The strip should be long enough so that the user can hold it securely in both hands, about one-fourth inch to three-eighths inch thick, and of a width appropriate to the size of the machine on which it will be used. Linen tape should be wrapped around the canvas wiper over the rivets to prevent all possibility of their coming in contact with the commutator. The canvas wiper is applied to the commutator

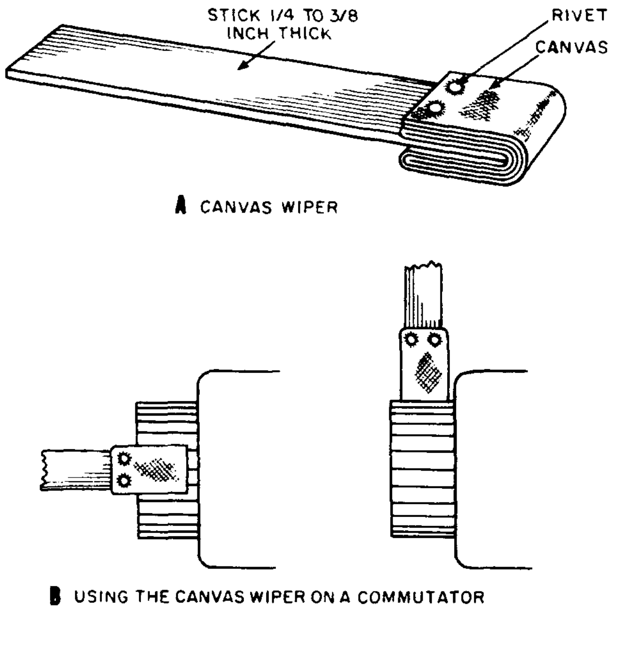

Figure 12-4.—Using the canvas wiper on a commutator.

in either of the ways illustrated in figure 12-4B. When the outer layer of canvas becomes worn or dirty, it is cut off to expose the next layer.

When the machine is secured, use a toothbrush to clean out the commutator slots, and wipe the commutator and adjacent parts with clean canvas or cheesecloth. Take care not to leave threads lodged between the commutator bars or on the brushes. Do not use cotton waste or any cloth that leaves lint.

Do not use solvents for routine cleaning of commutators, and do not use any lubricant on the commutator.

If the commutator is only slightly (blackened, scratched, or dirty) but not out of true (flat, grooved, or eccentric), a fine grade of sandpaper (No. 00) may be used. Sandpapering is also used to reduce high mica, or to finish a commutator that has been ground or turned. The machine is run under a light load at approximately rated speed. The sandpaper is attached to a wooden block that has a face shaped to the same curvature as the commutator. Move the sandpaper very slowly back and forth in a direction parallel to the axis of the machine. Rapid motion of the sandpaper will cause diagonal scratches. Do not use coarse sandpaper because this will make deep scratches. Do not use emery paper, emery cloth, or emery stone on a commutator as these materials contain carbon, which will become embedded in the commutator slots and short-circuit the armature coils.

MAINTAINING ANTENNAS AND TRANSMISSION LINES

Specific instructions for maintaining VHF/UHF and microwave antennas are given in the instruction book for a particular equipment or a particular antenna. Good practical information on testing antenna systems is included in chapter 4 (Testing Antenna Systems) of Shipboard Antenna Details, NavShips 900,121A. Equally helpful is the information on transmission lines contained in Installation and Maintenance of Transmission Lines, Waveguides, and Fittings, NavShips, 900,081. Another useful publication is Armed Services Index of R-F Transmission Lines and Fittings, NavShips 900,102B.

This portion of the chapter treats in a general way the use of meggers in testing antenna systems and the cleaning of antenna and transmission line insulators. However, before the

subject of testing antenna systems is treated you may wish to review the information on the ohmmeter and the megger in Basic Electricity NavPers 10086 (revised).

Basically, an ohmmeter (or the ohmmeter section of a multimeter) is used to determine if a circuit is open, shorted, or grounded; it is likewise used to determine the resistance of a circuit or component. It is simple to use. The test leads are connected to the instrument, and the range switch and the meter adjustments are made. The probes are then placed across the circuit or component to be tested. If no reading is obtained (infinite resistance), the circuit is open (or the resistance is so high that the meter will not give an indication); if a reading is obtained, the circuit is not open. If no resistance is indicated, the circuit or component is short-circuited. If the ohmmeter indicates essentially no resistance between a point in a circuit and ground, that point is grounded. The value of the resistance of a circuit or component is indicated on the meter dial.

In general, ohmmeters are used for low or medium values of resistance; meggers and insulation test sets are used for high values of resistance (perhaps hundreds of megohms).

USE OF INSULATION TESTERS IN TESTING ANTENNA SYSTEMS.—The theory of operation of the megger is discussed in Basic Electricity, NavPers 10086 (revised). Essentially, it consists of a d-c generator supplying a 2-branch circuit, which contains an indicating meter calibrated to read in megohms the unknown resistance inserted in one of the branches.

The megger is used to check the insulation resistance of antennas, transmission lines, cables, generators, motors, transformers, and so forth. Occasional checks over a period of time with a megger will show the condition of insulating material used on antennas, transmissions, etc, and in this manner indicated likely faults. It is also widely used to detect, or track down, insulation faults after they have occurred.

Another type of insulation test set (closely related to the megger) employing an a-c generator, a rectifier, and an ohmmeter circuit with a conventional d-c milliammeter (Insulation Test Set AN/PSM-2A) is illustrated in figure 12-5. It is designed to measure insulation resistance from 0 to 1000 megohms. The testing voltage is 500 volts d-c.

The meter pointer should read infinite resistance when there are no external connections to the output binding posts, L, and GND. If the pointer does not stand over the infinity mark, it is necessary to adjust the meter adjustment screw until the pointer stands over the infinity mark. When the meter terminals are short-circuited and the crank is turned at normal operating speed (indicator buttons glowing steadily), the meter pointer should be over the zero mark.

The operation of the insulation test set is relatively simple.

1. Be sure that the apparatus, line, or circuit to be tested is disconnected from its power supply in accordance with safety instructions. Ground the apparatus, line, or circuit to be tested to discharge any capacitors connected to it.
2. Connect the spade-type terminal lug of the black lead to the GND binding post of the test set.
3. Attach the alligator clip of the black test lead to the side of the circuit (under test) nearest ground potential.
4. Connect the spade-type terminal lug of the red lead to the L binding post of the test set.
5. Attach the alligator clip of the red test lead to the conductor to be tested.
6. Turn the crank in either direction at the minimum speed required to provide steady illumination of the indicator buttons.
7. Read the megohms of resistance offered by the material being tested. If the resistance is more than 1000 megohms at 500 volts d-c, the meter will remain at rest over the infinity mark (∞), indicating that the resistance of the insulation being tested is beyond the range of the meter.

Measuring the insulation resistance of lines and antennas is a very important and effective means of determining the condition of the antenna and its transmission line. Readings taken in these tests should be 100 megohms or greater, although lower readings will be registered on wet or humid days. Of course, megger tests are more meaningful if made during good weather. Some antennas have a d-c short circuit and therefore the insulation resistance cannot be measured directly; among those that are short-circuited with respect to direct current are the AT-150/SRC, the AS-390/SRC, the NT-66015, and the NT-66016.

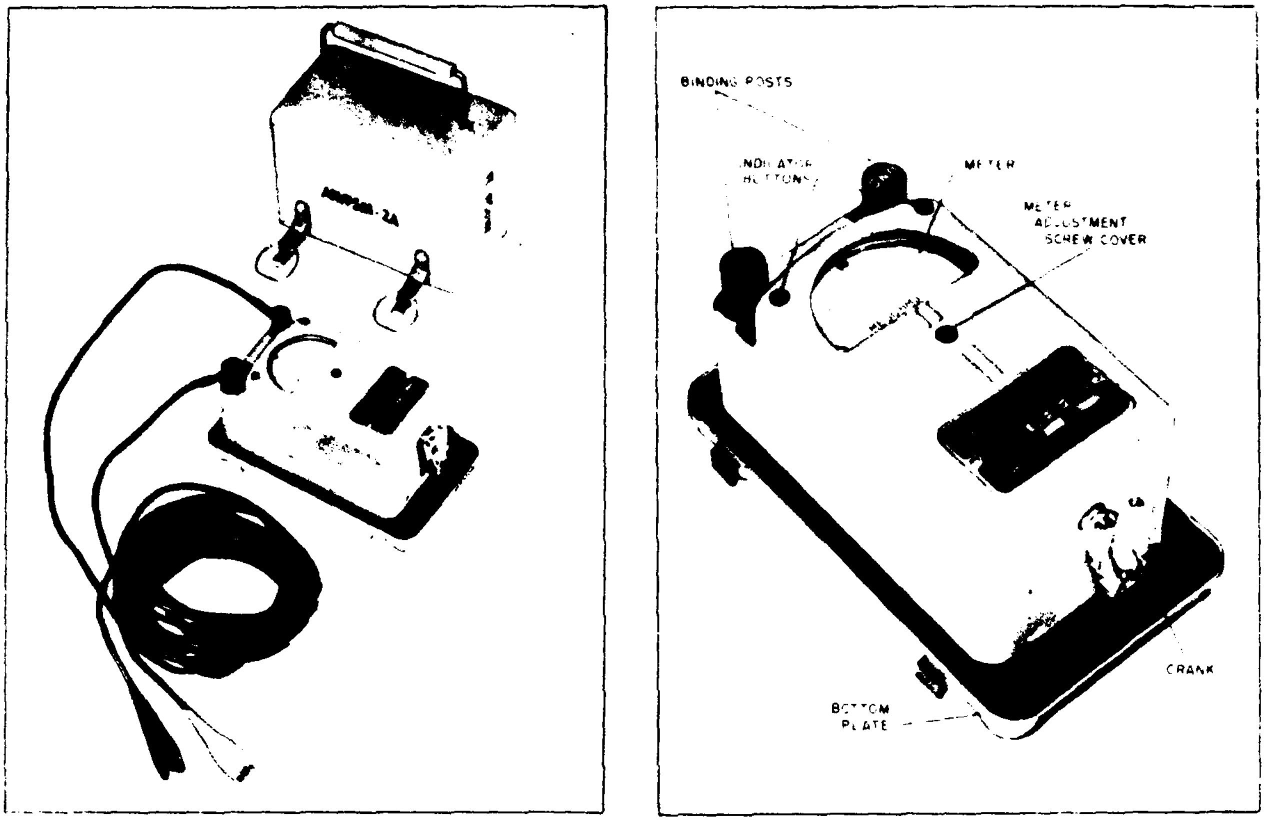

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Figure 12-5.—Insulation Test Set AN/PSM-2A.

Before performing any tests, the megger should be checked to determine if it is in good working order, as explained previously. Make good, positive, clean connections to antenna and ground, otherwise the contact resistance will be an appreciable part of the total megger reading.

For most antenna installations the test procedure is as follows:

1. Disconnect the transmission line at the equipment and test the line at this point. (NOTE: Do not connect the megger to the equipment at any time.)

2. If the reading registers below 100 megohms, disconnect the transmission line at the antenna and test individually both the transmission line and the antenna at this point. This will indicate that the trouble lies either in the transmission line or the antenna or both.

3. If the trouble (low-resistance indication) is shown to be in the transmission line, disconnect the line at the various coaxial connectors and test the individual sections of the line to further localize the trouble.

4. If the trouble (low-resistance indication) is shown to be in the antenna, the antenna will have to be repaired. (However, it should be recalled that certain antennas normally contain a d-c short circuit. The resistance of these antennas should be approximately zero ohms, as indicated on a low-reading ohmmeter.)

These tests are made at prescribed intervals, and the readings are recorded on the proper forms (the Maintenance Standards Books, Resistance Test Record Card, etc.).

Continuity checks are also made with the megger or a multimeter. In performing these tests, the transmission line is disconnected at both ends. At one end, the inner conductor is shorted to the outer shield. At the other end, the resistance between the inner conductor and the outer conductor is measured.

The following three steps, taken from the Maintenance Standards Book, Part II, Preventive Maintenance Check-Off for Radio Receiving Sets AN/SRR-11, 12, 13, NavShips 91875.41, will illustrate the routine measurements made on the antenna and transmission line. The steps are indicated in table 12-1 and the connections are illustrated in figure 12-6.

Four of the steps used in testing the antenna and transmission line of Radio Transmitting Sets AN/SRT-14, 15, 16 are illustrated in figure 12-7 and table 12-2. These steps are taken from Part II, Preventive Maintenance Check-Off for these transmitting sets.

NOTE 1: The jumper wire must be connected from the inner conductor to the outer conductor. The jumper wire should be as short as possible and the connections must be good. The resistance indicated is that of the inner conductor in series with the outer conductor and should be low (a fraction of an ohm).

NOTE 2: With the switches in the positions indicated, continuity is provided from the antenna through the antenna cable, and through the antenna coupler loading switches to a loading capacitor that blocks the d-c path to ground through the tuning coils. The resistance indication should be very high.

NOTE 3: With the switches in the positions indicated, continuity is provided from the meter, through the antenna cable, the antenna coupler, the cable from antenna coupler to the r-f tuner, the r-f tuner coils to ground, and back to the meter. The resistance indicated should be a small fraction of one ohm.

Table 12-1. Antenna and Transmission Line.

Operating Conditions and Control Settings:
nna and transmission line
nected from Radio
ving Set AN/SRR-11, -12, or -13

Test Equipment Required:
Multimeter AN/PSM-4
Navy Model OCW Insulation Resistance Test Equipment

Step No.	Step Action Required	Preliminary Action	Read Indication On	Perf. Std.
1	Record resistance of transmission line.	Connect equipment as shown in fig. 12-6. Set Multimeter AN/PSM-4 function switch: Rx1.*	Multimeter AN/PSM-4	_ohms (See note at bottom of chart.)
2	Record insulation resistance of transmission line.	Connect equipment as shown in fig. 12-6.	Insulation Resistance Navy Model OCW Test Equipment.	_meg (50 or higher.)
3	Record insulation resistance of antenna.	Connect equipment as shown in fig. 12-6.	Insulation Resistance Navy Model OCW Test Equipment.	_meg (50 or higher.)

*When recording resistance of transmission line, the jumper wire must be connected from inner conductor to outer conductor. This method of connection provides continuity from meter, through inner conductor, jumper wire, and outer conductor, back to meter. Resistance reading will therefore be resistance of outer conductor plus resistance of inner conductor. To avoid error due to jumper wire connection, jumper wire must be kept as short as possible, and connections must be good. The resistance reading obtained in this step depends upon length and type of transmission line. For all normal installations, resistance is a small fraction of one ohm.

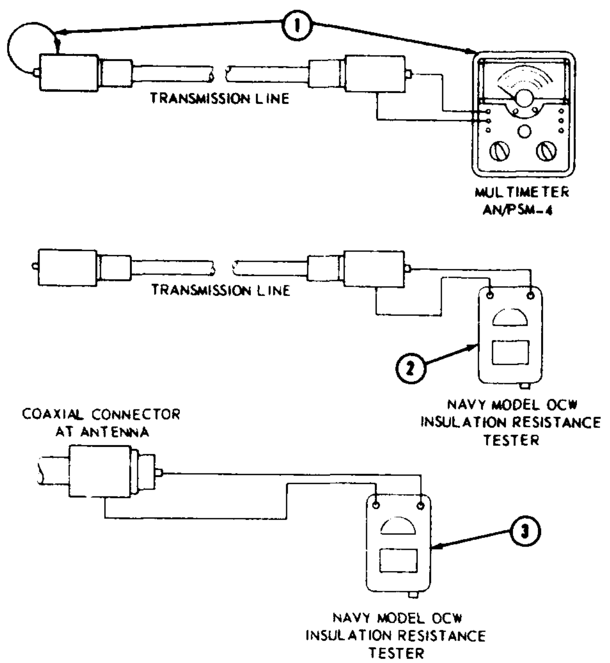

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Figure 12-6.—Meter connections for making antenna and transmission-line measurements (receiver).

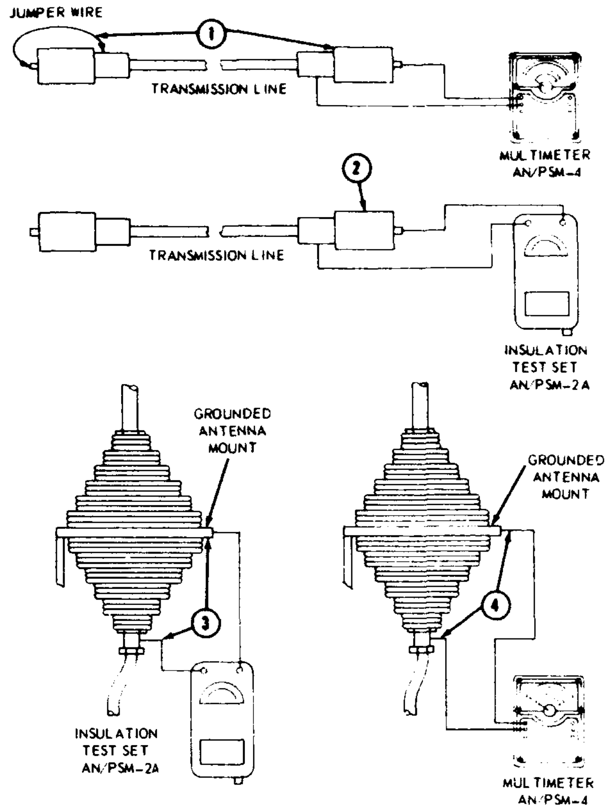

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Figure 12-7.—Meter connections for making antenna and transmission-line measurements (transmitter).

CLEANING INSULATORS.—Leakage current over the surface of an insulator is usually due to moisture and impurities on the surface such as salt spray, soot, or dust.

All standoff insulators, end seals of transmission lines, and waveguide windows should be cleaned at least once a month, and more often if conditions warrant.

The smaller the insulator, end seal, or waveguide window, the more important is this maintenance procedure. The cleaning must be thorough with nothing left to chance.

Paint, varnish, shellac, or grease must not be applied to any portion of ceramic or phenolic insulating materials forming a part of the antenna system.

TESTING ELECTRON TUBES

The leading cause of failure or poor operation of electronic equipment (transmitters as well as receivers) is the electron tube. If all tube failures could be eliminated, the maintenance load would be reduced considerably. Tubes do not always collapse completely. Their performance may gradually deteriorate but not to the extent that it will be apparent in a tube checker. One reason for the failure of the average tube checker to give a full indication of the capabilities of a tube is the 60-cycle sine wave that is applied to the grid of the tube under test. In electronic equipment, all kinds of wave shapes may be applied at frequencies varying from a few cycles to several billion cycles per second. The usual shipboard tube tester cannot determine accurately the ability of a tube to act as an oscillator or as an ultra high frequency amplifier.

Because of the importance of the method of using the tube checker, the Bureau of Ships has issued an instruction (BuShips Inst. 9670.89) establishing the general policy for testing electron tubes.

Table 12-2.—Operating Conditions and Control Settings.

Operating Conditions and Control Settings:
All transmitter Primary Power switches set to OFF position; Antenna and Transmission lines disconnected.

Steps 1 through 4 Test Equipment Required: Multimeter AN/PSM-4 Insulation Test Set AN/PSM-2

Step		Preliminary Action	Read Indication On	Perf. Std.
No.	Action Required			
1	Record transmission line resistance. (See Note 1.)	Connect Multimeter AN/PSM-4, using R x 1 ohmmeter scale, from inner conductor to output conductor of transmission line. Connect jumper wire from inner to outer conductor at opposite end of transmission line. Record resistance (a) of line from transmitter to Antenna Coupler, and (b) from Antenna Coupler to Radio Frequency Tuner.	Multimeter AN/PSM-4.	(a)_ohm (b)_ohm
2	Record transmission line insulation resistance.	Connect Insulation Test Set AN/PSM-2 from inner to outer conductor of (a) transmission line from transmitter to Antenna Coupler, and (b) transmission line from Antenna Coupler to Radio Frequency Tuner.	Insulation Test Set AN/PSM-2.	(a)_meg (b)_meg (50 or over.)
3	Record antenna insulation resistance. (See Note 2.)	Reconnect all transmission lines. Set Antenna Transfer switch to TUNER IN, ANTENNA COUPLER LOADING switch to A, and TRANSFORMER switch to DIRECT. Connect Insulation Test Set AN/PSM-2 as shown in fig. 12-6 and record insulation resistance.	Insulation Test Set AN/PSM-2.	_meg (50 or over.)
4	Record antenna cable resistance. (See Note 3.)	With all antenna cables connected, set ANTENNA TRANSFER switch to TUNER IN, ANTENNA COUPLER LOADING switch to DIRECT, and TRANSFORMER switch to DIRECT. Connect multimeter AN/PSM-4, using R x 1 ohmmeter scale, as shown in fig. 12-6.	Multimeter AN/PSM-4.	_ohm

Table 12-2.—Operating Conditions and Control Settings—Continued.

Time Schedule: Record and initial.
Approx. Time Reqd. for Quarterly Steps—3 hrs.

Quarter		1st Quarter 19—	2nd Quarter 19—	3rd Quarter 19—	4th Quarter 19—
Step 1	a				
	b				
Step 2	a				
	b				
Step 3					
Step 4					
Initial					

The practice of wholesale removal and test of electron tubes on a periodic basis has been discontinued. If routine test of an electron tube in a designated application is necessary, the instruction book will specify an exception to the rule.

The following maintenance routine is strongly recommended:

1. When a performance deficiency is detected, make an all-out attempt to isolate the specific cause.
2. When the trouble has been localized and a tube is suspected, remove and test that tube. If found good, replace in the same socket. Interchange of tubes between sockets should be avoided.
3. If repair by tube substitution is necessary as a last resort, test the new tube (within the capability of the tube tester) before placing it in service.
4. If a new tube tests good but will not work in a particular socket, make a note of this fact and save the tube for use in another application where it will work. The Bureau of Ships is particularly interested in receiving information on cases where extensive selection of tubes for a particular socket is necessary for proper operation. Failure Report Forms (DD787) and Performance and Operating Reports (NavShips 3878 revised) are convenient ways to do this.

TESTING CRYSTAL DIODES

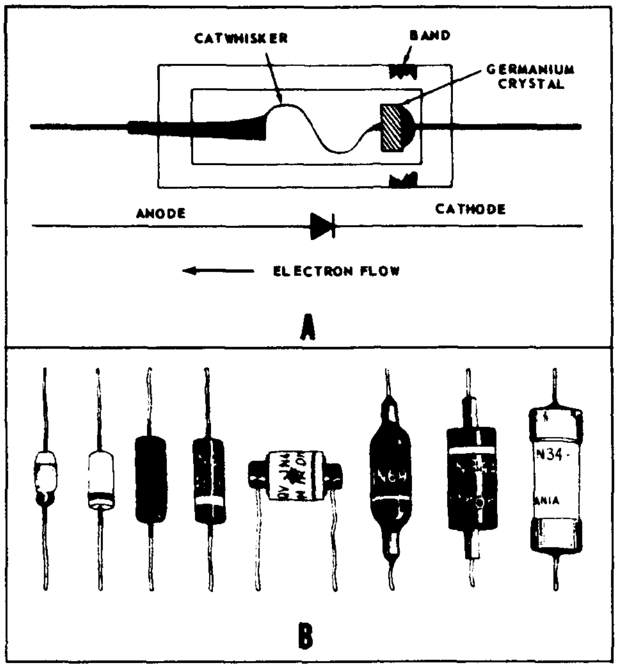
Navy electronics technicians usually will be working with three types of crystal diodes: General-purpose germanium and silicon diodes, power silicon diodes, and forward and reverse high-frequency silicon diodes (commonly called mixer crystals).

A sectional view of a typical germanium crystal diode is illustrated in figure 12-8A. A number of different types of crystal diodes are illustrated in part B. Germanium diodes are usually enclosed in a plastic or glass cylindrical case with pigtail connections.

The cathode end, usually marked with a painted band or other distinctive marking, contains a small crystal of N-type germanium. A thin catwhisker wire makes a point contact with the crystal. Electrons will flow easily from the germanium into the catwhisker; this makes the catwhisker the anode and the crystal the cathode. Some diodes of this design are being made with silicon crystals in place of the germanium. Silicon power diodes are just beginning to be produced. Their outputs and operating temperature are considerably above those of germanium.

Germanium diodes, such as the 1N34A or 1N69, are used for a wide range of applications, such as video, audio, and pulse circuits. Many are used as detectors in radio and television equipment, and as mixers at frequencies up to 900 megacycles.

Mixer crystals, such as the 1N21 or 1N23, are designed for microwave detection and mixing. These are very carefully made diodes, with low-loss ceramic barrels and machined and gold-plated brass tips and bases for close fits in waveguides and coaxial fittings. Two 1N23B



1.58
Figure 12-8.—Germanium crystal diodes.

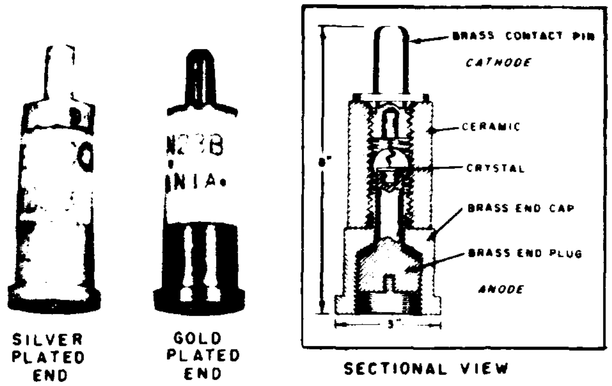
silicon crystal diodes are shown in figure 12-9; a sectional view is also shown.

A small crystal of almost pure silicon acts as a P-type semiconductor. Electrons will pass easily from the catwhisker to the silicon, making, in effect, the base the anode and the tip the cathode. Mixer crystals of this type are available for use with frequencies from 1000 to 10,000 megacycles.

Diodes for 10,000 megacycles and above are usually of the coaxial type, as shown in figure 12-10.

Reverse crystal mixers (for example, the 1N23CR) cause considerable confusion. Reverse polarity crystals (fig. 12-11A) are identical in characteristics to the ordinary type (fig. 12-11B) whose number they carry. Thus, a 1N23CR is identical electrically to a 1N23C except for the reversal of polarity. The crystal in the reverse type (1N23CR) is fastened to the tip, making the tip the anode and the base the cathode. In the ordinary type the crystal is fastened to the base, making the base the anode and the tip the cathode.

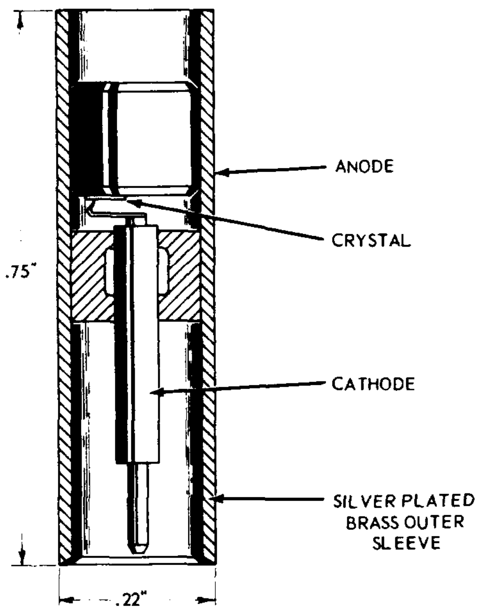
The properties of the crystal rectifier depend on the pressure, the contact area, the place of contact, etc. This has been carefully adjusted at



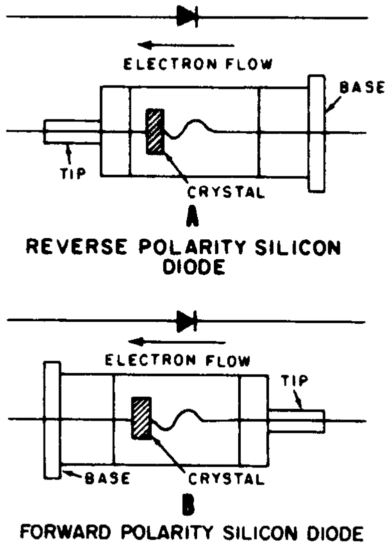
1.59
Figure 12-9.—Cartridge-type silicon crystal diodes.

the factory and should not be upset by tampering with the set screw.

The area of the contact is very small, and if too much power is passed through the cartridge, the resulting heat will damage it, and the crystal rectifier will be impaired. The



1.60
Figure 12-10.—Sectional view of coaxial silicon crystal diode.



1.61
Figure 12-11.—Reverse and forward-polarity silicon diodes.

crystal rectifier may be damaged, for example, by a static discharge through it. If the ET holds one end of the crystal and touches the equipment with the other end, any static charge on his body will discharge through the crystal mixer. He should first touch his finger to the mixer chassis and then insert the crystal rectifier in its holder, as illustrated in figure 12-12.

A crystal may also be damaged by exposure to a strong r-f field. Therefore crystal rectifiers must be kept in a metal box or wrapped in metal foil except when in use or being tested.

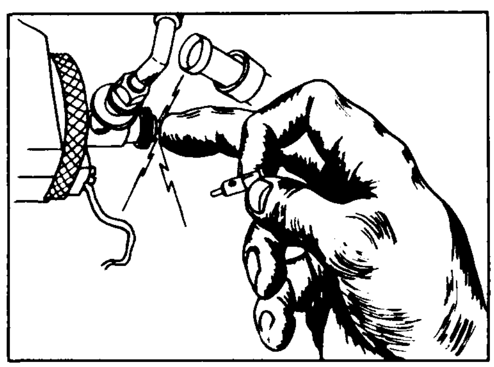
In radar equipment in which a crystal rectifier is used, it is normally protected by a TR tube. The purpose of the TR tube is to place a short across the line leading to the crystal rectifier by means of gas breakdown in the tube during the firing of the main transmitter pulse. The returning signal, or echo, is much smaller than the transmitter pulse and does not cause a breakdown. It therefore comes through to the crystal rectifier. During the main pulse, some power does leak through the TR tube because it is not a perfect short. However, this power is normally small enough not to damage the crystal.

It is obvious that if the TR tube does not function properly, the crystal rectifier may be damaged. Improper functioning may be due either to the fact that the TR tube is defective or there is incorrect TR tuning (if tuning adjustments are provided).

Another possible cause of crystal damage is a distortion of the pulse shape of the modulator. If the pulse has a sharp peak at the beginning (instead of the usual square shape), much more power will come through the TR tube than for a square pulse of equal energy (because of insufficient time for the blocking action to occur) although the TR tube may be operating normally. Faulty TR operation and distorted modulator pulses are the two main causes of crystal rectifier impairment. Continued impairment of good crystal rectifiers is an indication that the TR tube and the modulator should be checked.

The deterioration of the crystal rectifier in a receiver produces an increase in noise or a decrease in signal, or both, assuming that other factors (for example, receiver gain, transmitter strength, and target distance) remain the same. Such a change results in a decrease in the signal-to-noise ratio; and it is the signal-to-noise ratio that determines the over-all merit of a receiver. Other possible causes of a low signal-to-noise ratio are improper functioning of the first IF stage (pre-IF), or excessive losses between crystal and first IF stage (such as in the cable or connectors), or improper tuning of the local oscillator.

If produced gradually, the impairment of a crystal rectifier is quite difficult to notice. One method of detecting the impairment is to compare the operation of the crystal rectifier with that of

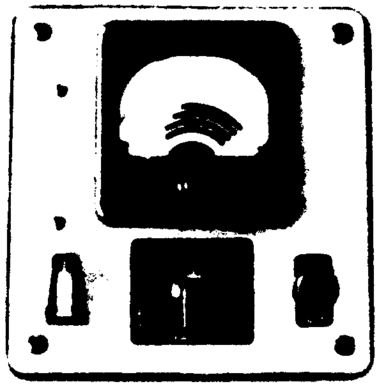


1.62
Figure 12-12.—Reinserting crystal rectifier in mixer.

a new one. If, under the same operating conditions, the noise is less or the signal is greater with the new crystal, the old crystal is probably impaired. However, if the crystal rectifier current remains unchanged, it does not necessarily mean that the crystal rectifier is unimpaired.

To test a crystal rectifier properly and completely is an elaborate matter and requires precision test equipment. However, the crystal rectifier tests sets, Model TS-268/UTS-268/U Series, supplied for Navy ET's are sufficiently accurate for field use.

A front view of Model TS-268/U Crystal Rectifier Test Set is shown in figure 12-13. The limits (minimum forward-to-reverse resistance ratio and maximum reverse (back) current) established by laboratory tests are shown in table 12-3.



1.63

Figure 12-13.—Front view of Crystal Rectifier Test Set TS-268/U.

Table 12-3.—Crystal Rectifier Limits.

Crystal Rectifier Types	Backward-to-Forward Resistance Ratio (minimum)	Back Current in ma (maximum)
1N21	10/1	0.40
1N21A	10/1	0.175
1N21B	10/1	0.125
1N23	10/1	0.4
1N23A	10/1	0.3
1N23B	10/1	0.175

TESTING TRANSISTORS

Transistors may be tested "in-circuit" or "out-of-circuit." Also, the tests may be either d-c, where the measurements are made by d.c. test equipments, or a-c where there is an a-c input to the base circuit and an output from the collector circuit. A-c measurements may be made either in-circuit or out-of-circuit. D-c measurements can be made out-of-circuit only; otherwise, the measurements might be affected by equipment d-c or biasing voltages.

Precautions to take before making any transistor test:

1. Make sure that all power has been removed from the equipment under test before servicing, testing, or removing a transistor or transistorized assembly.

2. Before employing any test equipment, it should first be determined that the test instrument meets the requirements for the test and type of circuit.

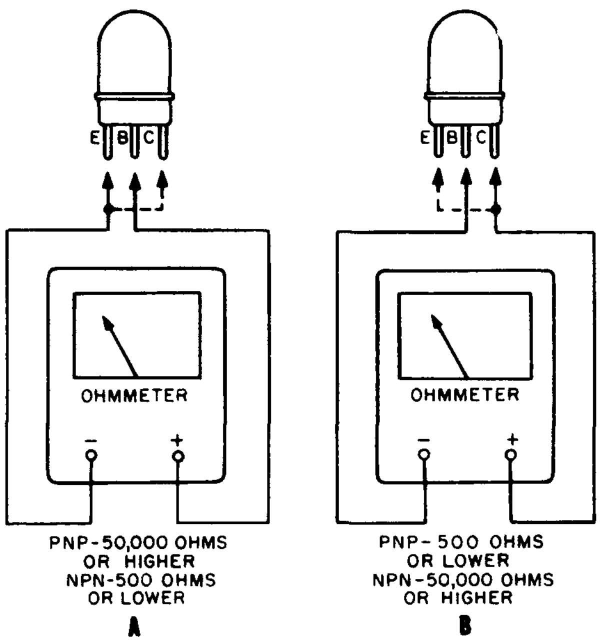
3. Be sure that any line-powered test equipment has been properly grounded to the chassis of the equipment under test.

4. Check the test equipment circuit on all ranges, to be sure that it does not pass more than 1 milliampere of current through the transistorized circuit under test. More amperage cannot safely be used for testing most transistor circuits. Use a low-resistance milliammeter in series with the test leads for this check.

5. Before making any measurements, be sure that any voltage applied is of the correct polarity for the circuit under test. Do not depend on the indicated polarity; use a voltmeter in series with the test leads for this check.

6. Do not troubleshoot transistor circuits by the shorting-to-ground method. Short circuits of any kind will damage a transistor. Extreme care must be taken to avoid these shorts—use special insulated test probes to prevent accidental shorting.

A rough check may be made on a transistor by means of d-c tests that will determine its forward and backward resistances and also any leakages or shorts. Connections for these tests are shown in figure 12-14. With the positive ohmmeter lead connected to the base of a PNP transistor (fig. 12-14A) a high-resistance reading (50,000 ohms or higher) should be obtained between base and emitter, and between base and



70.102
Figure 12-14.—Transistor resistance testing.

collector. With the negative ohmmeter lead connected to the base of a PNP transistor (fig. 12-14B) the resistance between the base and collector and between the base and emitter should be 500 ohms or less. If the same ohmmeter tests are made on an NPN transistor, the results will be reversed; that is, the high-resistance readings will be obtained with the negative ohmmeter lead connected to the base, and the low-resistance readings with the positive ohmmeter lead connected to the base. If the correct resistance readings are not obtained from the ohmmeter test, the transistor should be replaced.

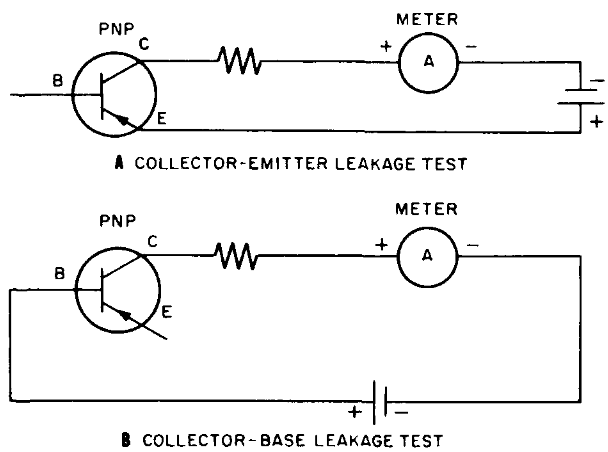
This type of test may also be used for determining the type of a transistor, PNP or NPN, when its type is unknown. With the test connection as in figure 12-14A, a high-resistance reading (50,000 ohms or higher) shows that it is a PNP type; a low-resistance reading (500 ohms or less) shows that it is an NPN type.

In checking transistors, there are two basic tests—collector current leakage and transistor gain, or amplification.

Age and exposure to higher-than-normal temperatures may develop greater-than-normal collector leakage current, generally designated as I_{CO}. Such current is greatly dependent on ambient temperature; thus extreme care must be taken to see that this temperature remains under control. One positive sign of a defective transistor is instability of I_{CO}. When there is a tendency for the leakage current to climb slowly of its own accord, it is quite evident that the transistor is defective. A high leakage current indicates a deterioration of the transistor, and is usually accompanied by lower gain.

As illustrated in figure 12-15, collector leakage current tests may be made in two ways. Figure 12-15A shows the connections for checking the leakage current in the collector-emitter circuit, with the base open. Figure 12-15B shows the connections for checking the leakage current in the collector-base circuit, with the emitter open. Any contamination on the surface of the transistor, or a short circuit within, will produce a high current reading on the meter.

In comparing the two test arrangements, the only advantage of the test in figure 12-15A is that, since the collector-emitter circuit is of low resistance (possibly about 1000 ohms), normally there will be sufficient leakage current to be read on a milliammeter, which is nearly always available. However, the test outlined in figure 12-15B requires a much more sensitive instrument, and is to be preferred if a suitable instrument is available. Since the transistor is reverse-biased (PNP-type transistor with negative terminal of battery toward collector), the



70.103
Figure 12-15.—Collector leakage current test, schematic diagram.

reverse current is very small. It is a high-resistance circuit (on the order of 50,000 to 70,000 ohms), and the leakage current is usually no more than 10 to 15 microamperes. Such small currents are best measured on a transistor test set, which is usually provided with a sensitive microammeter.

Since one of the primary functions of a junction transistor is amplification, one of the basic tests, in addition to the collector leakage test, is a check of gain (or amplification), designated BETA. The gain test is a measurement of the change in collector current for a small change in the base current.

All of the current in a transistor is supplied by the emitter, of which more than 90 percent goes to the collector and the remainder to the base. Where, for example, 95 percent of the current goes to the collector and 5 percent to the base, then beta = 95/5 = 19. A beta of 19, then, means that for any change in current in the base, the change in the collector will be 19 times as great.

To measure beta, approximately, correct results can be obtained by removing the transistor from the equipment and using d-c test methods. Better results can be obtained, however, when the test is made under operating conditions, using a-c test methods. This test can best be accomplished by use of a transistor test set designed specifically for the purpose, such as the transistor test set, TS-1100.

MAINTAINING EARPHONES AND MICROPHONES

The best way to maintain earphones and microphones is to ensure that they are handled properly. Proper handling includes, for example, hanging up earphones by the straps, not by the cord; removing a plug from a jack by grasping the plug, not the cord; avoiding kinks or other strains in the cord; avoiding rough handling of microphones and earphones, and avoiding exposure to moisture. Heat lamps may be used to protect or to dry out carbon microphones.

Repair consists largely of replacing or repairing plugs, jacks, and cords. In any case, do not place defective equipment with the ready spares. It should be repaired first.

MAINTAINING RADIO TRANSMITTERS

The correct preventive maintenance procedure for any type of transmitter is included in the instruction book that accompanies the equipment. It is the purpose of this portion of the chapter to list some of the general procedures used in maintaining one type of transmitter (Radio Transmitting Sets AN/SRT-14, 15, 16). The operation of this transmitter is discussed in chapter 9 of this training course.

GENERAL MAINTENANCE.—The ET should make every effort to become familiar with the equipment in order that he may be able to recognize and anticipate avoidable defects. Table 12-4 will be of assistance in making these observations.

The radio frequency amplifier meter readings (power amplifier current, intermediate power amplifier current, and voltmeter) should be taken under the same conditions and with the same antenna or dummy load. Weekly readings are to be made and compared with those of the previous week so as to check the various conditions existing. It should be borne in mind that production-line tubes will vary considerably in their current output readings. However, a definite trend or fluctuation in the readings is to be interpreted as an indication of trouble. By charting these fluctuations, a reliable record of tube performance is available for ready reference and trouble may be avoided by changing tubes before a critical stage is reached.

Complete instructions for taking and recording the meter readings are given in eleven steps in the POMSEE book (Part II, Preventive Maintenance Check-Off) for this equipment. The meters to be read in performing steps 3, 4, and 5 are illustrated in figure 12-16. Page five of Part II, Preventive Maintenance Check-Off (which lists the operating conditions and control settings for steps 3, 4, and 5) is reproduced as table 12-5. Following page five are charts for recording the weekly meter readings associated with steps 3, 4, 5.

Some general maintenance procedures may be listed as follows:

1. Check for unusual odors, such as that of hot potting compound, which might indicate an overloaded transformer; burning paint, due to overheated resistors; and burning rubber, due to excessive current through a rubber-covered conductor.
2. Use an air hose to remove dust, dirt, and foreign particles. Extreme care must be exercised when the air hose is used around delicate

Table 12-4.—Initial Checks.

Item	Check
1. Primary Power	The ship power supply must be available at all times.
2. Control Equipment	Radiophones, teletype; facsimile, hand keys and other control equipment must be in good working order and connected properly.
3. Insulators	Antenna and line insulators must be kept clean and free of unwanted grounds.
4. Cables	All internal and external cables must be firmly and properly connected.
5. Dirt and	Leakage paths are often caused by dirt and moisture, resulting in arcovers and loss of efficiency.
6. Loose Parts	In operation, some mountings or fittings may work loose or become damaged. Correct this condition as quickly as possible.
7. Visual Check	Check for broken, damaged, or loose hardware; meters; knobs; dials; or lamps. Replace damaged parts without delay.

parts such as tuning capacitors. As a precautionary measure, the air line should be purged of moisture by directing the nozzle toward the floor and releasing the air in the line before directing it toward the equipment.

3. Avoid, if possible, disturbing the layout of the wiring. If wiring must be removed, be sure to return it to its original position after the cleaning procedure to prevent oscillation, feedback, and other circuit disturbances. Check all sockets, and remove any dirt or corrosion with solvent or with fine sandpaper or crocus cloth.

4. After cleaning, inspect the equipment for faulty or damaged parts. Some of these parts include tube sockets and contacts, springs, gears, tuning capacitors, potentiometers, bandswitches, insulators, terminal strips, jacks, plugs, and hinges. Check for and replace or secure loose or damaged hardware.

5. The operating controls should be given a careful visual inspection and then checked for correct operation and setting. Turn each control slowly to its maximum clockwise limit, then to its maximum counterclockwise limit. Binding or scraping should be noted and corrective measures taken.

6. In gear assemblies and in tuning mechanisms backlash must be held to a minimum. Hence, trouble of this sort should be noted and corrected or reported as soon as possible.

7. Replace damaged parts, such as shorted or leaky capacitors or burned out resistors. However, before actual replacement of the damaged part, the circuit should be carefully inspected to find the cause of the trouble. Only in extreme emergencies should replacement be made without a checkup.

8. It is important to remove dirt or corrosion on the prongs of plug-in parts, such as tubes, jacks, and plugs, to avoid a high-resistance connection between the prong and its socket. Use crocus cloth or fine sandpaper.

9. Cables and cords and their jacks and plugs must be checked for damage to their inserts and insulation. Look for opens, shorts, and intermittent contacts. The latter may often be found by wiggling the plugs in their sockets. If damage is found, or if trouble is suspected, use an ohmmeter to check for continuity in the cords and cables.

LUBRICATION.—The lubrication procedure is spelled out in the instruction book.

When dispensing a lubricant, wipe all dirt, dust, or moisture from around the opening of the container. The containers must be kept closed when not in use to prevent moisture condensation on the surface of the lubricant and to keep dust and dirt out of the container. It is extremely important that lubricants be kept free of foreign matter.

Many of the bearings used in this particular equipment are made of oil impregnated bronze and require no lubrication.

Special Maintenance.—Noise, loss of sensitivity, and improper tuning may be caused by faulty or dirty tuning capacitors. (Serious losses may also occur in certain other tuned circuits.)

Rotor contacts, bearings, and plates may be cleaned with an approved solvent. Pipe cleaners (if available) are especially useful for cleaning between capacitor plates. A small brush, dipped in solvent, may also be used for this purpose. Be careful not to damage or bend any of the plates.

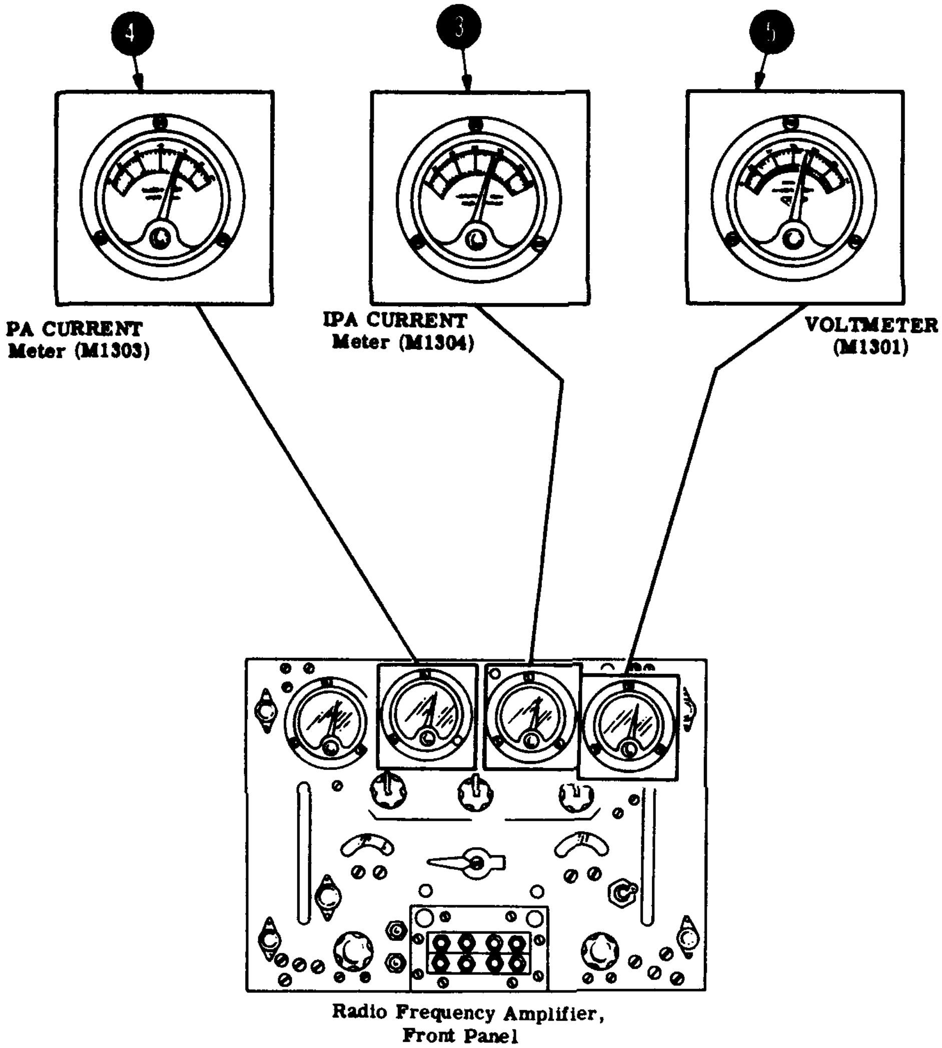


Figure 12-16.—Meters to be read in performing steps 3, 4, and 5 in part II, Maintenance Standards Book.

Some relay contacts are plated with thin coats of silver. In cleaning this type of contact, avoid the use of abrasives, which may damage the contact surfaces. These surfaces are cleaned with solvent.

Pitted contacts on heavier relays, such as those used for power contact circuits, are cleaned with a fine grade of crocus cloth. Badly pited contacts should be replaced singly, if possible; if not, a complete new relay may have to be installed. After being cleaned, the contacts or relays are finished with a burnishing tool.

The moving parts of relays are checked as follows:

1. Check the armature pivot points. They should be free of burrs, rust, corrosion, or any other defect that may prevent free movement. Remove burrs or corrosion with a fine file or fine sandpaper. However, be sure that the shape and location of the pivot points have not been changed.

2. The return spring should be inspected for correct tension. Replace the spring if rusted or damaged.

3. Examine the relay winding for damage to the insulation. Damaged wires or insulation may be repaired with tape or insulated tubing (spaghetti).

4. Check the relay core for corrosion. If corroded, the relay should be replaced to avoid possible future failure.

5. Check the frame; repair or replace if damaged.

Wafer switches and detents should be examined carefully to ensure firm spring tension. Weak spots require restoration of spring tension. However, long telephone-type switch or relay contacts should never be bent. These contacts should be replaced, if possible. If the contacts cannot be replaced singly, the entire switch may have to be replaced, because poor contact pressure leads to trouble and eventual failure.

Check the detent actions and the switch shaft. These parts, as well as the switch contacts, may be cleaned with solvent. The various detent assemblies, especially those in the various subunits of the RFO, need careful attention. After a switch or detent has been cleaned, the part should be relubricated as directed in the instruction book.

When inspecting the miniature sprocket-type chains, be sure to check the adjustment of the sprocket idlers. Proper tension on the chains must be maintained at all times. To achieve correct tension, a balance must be found which

Table 12-5.—Operating Conditions And Control Settings.

Operating Conditions and Control Settings:
Transmitter adjusted for 100-watt, CW operation.
TEST KEY: locked ON position.

Step		Preliminary Action	Read Indication On	Perf. Std.				
No.	Action Required			mc	I_{c1}	I_{c2}	I_k	
3 **	Record IPA METER readings.	Set IPA METER SELECTOR switch (S1386) to I_{c1}, I_{c2}, and I_k, in turn. Record meter indication for each position and with transmitter adjusted for each of the frequencies indicated in PERF. STD. column.	IPA CURRENT meter (M1304).	.35	____	____	____	ma
				2.5	____	____	____	ma
				5.5	____	____	____	ma
				6.5	____	____	____	ma
				11.0	____	____	____	ma
				15.5	____	____	____	ma
				16.5	____	____	____	ma
				21.0	____	____	____	ma
				25.5	____	____	____	ma
					(0.1 to 2)	(4 to 8)	(50 to 85)	
4 **	Record PA METER readings (100-watt operation).	Set PA METER SELECTOR switch (S1386) to I_{c1}, I_{c2}, and I_k, in turn. Record meter indication for each position and with transmitter adjusted for each of the frequencies indicated in PERF. STD. column.	PA CURRENT meter (M1303).	.35	____	____	____	ma
				2.5	____	____	____	ma
				5.5	____	____	____	ma
				6.5	____	____	____	ma
				11.0	____	____	____	ma
				15.5	____	____	____	ma
				16.5	____	____	____	ma
				21.0	____	____	____	ma
				25.5	____	____	____	ma
					(10 to 20)	(20 to 80)	(150 to 300)	

Table 12-5.—Operating Conditions And Control Settings—Continued.

Step No.	Step Action Required	Preliminary Action	Read Indication On	Perf. Std.
5 **	Record VOLT-METER indications.	Set VOLTMETER switch (S1384) to BIAS, LV, MV, PA E_{c2}, and PA E_b, in turn. Record meter indication for each position and with transmitter adjusted for each of the frequencies indicated in PERF. STD. column. Set SERVICE SELECTOR switch (S1101): PHONE. Set VOLTMETER switch (S1384): PA E_b.	VOLTMETER (M1301).	mc BIAS LV MV .35 ____ ____ ____ VDC 2.5 ____ ____ ____ VDC 5.5 ____ ____ ____ VDC 6.5 ____ ____ ____ VDC 11.0 ____ ____ ____ VDC 15.5 ____ ____ ____ VDC 16.5 ____ ____ ____ VDC 21.0 ____ ____ ____ VDC 25.5 ____ ____ ____ VDC (-210 to -230) (270 to 330) (450 to 550) mc E_{c2} E_b E_b PH .35 ____ ____ ____ VDC 2.5 ____ ____ ____ VDC 5.5 ____ ____ ____ VDC 6.5 ____ ____ ____ VDC 11.0 ____ ____ ____ VDC 15.5 ____ ____ ____ VDC 16.5 ____ ____ ____ VDC 21.0 ____ ____ ____ VDC 25.5 ____ ____ ____ VDC (950 to 1150) (1200 to 1400) (270 to 330)

is a compromise between ease of operation and minimum backlash. In case of severe damage to the chain, it should be replaced. Remove dirt and grease with solvent.

MAINTAINING RADIO RECEIVERS

INSPECTION, CLEANING, AND ADJUSTMENTS.—The instruction book for each radio receiver lists certain preventive maintenance procedures that must be followed if the equipment is to be maintained in peak operating condition. Of course the instructions will vary, depending on the particular type of receiver, but the preventive maintenance instructions for Radio Receiving Sets AN/SRR 11, 12, 13 are typical.

The MONTHLY checks include the following: (1) Inspect to determine if the mounting bolts in the cabinet are tight, and tighten mounting bolts and all external fasteners when loose; and (2) inspect cords and plugs for wear and broken parts. Replace any cord that causes clicking sounds in the earphones when shaken during operation.

The QUARTERLY checks include the following: (1) Remove and replace the chassis in the cabinet. (If the chassis binds on the rails, adjust the chassis tilting fulcrum accordingly and lubricate according to the instruction book.); (2) check each plug-in unit for loose connections and appearance of the component. If the components show signs of overheating, apply corrective maintenance, as given in the instruction book; (3) inspect the chassis for loose interstage connectors (multisockets) on the chassis, and tighten as required; (4) inspect the band selector and reception control for loose crank pins that connect to the wafer shafts. If pins are loose they should be tightened according to the

instructions given in the instruction book; and (5) remove dust from the chassis and assemblies by the use of a small blower. Remove excess lubricant from the band switch and reception control racks, miter gears, and dial gears. After the cleaning is accomplished, the equipment is lubricated according to instructions.

The SEMIANNUAL checks include the following: (1) Inspect spare assemblies for evidence of physical damage; (2) check alignment of tuning dial and the operation of the dial light, check the mirror assembly (mirror used for reflecting the frequency scale onto the groundglass screen), and align the tuning dial and clean the mirror according to instructions. Another semiannual check is that of receiver sensitivity. This is somewhat involved and is treated separately in the following section.

SENSITIVITY CHECK.—The setup for checking the sensitivity of the AN/SRR-11, 12, 13 receiving sets is shown in figure 12-17. Sensitivity checks (in microvolts) are made at various frequencies in the five bands covered by the receiver and under various operating conditions—for example, A1 broad and FSK, A1 sharp, A2, A3 broad, and A3 sharp.

Details for making the sensitivity checks are included in the instruction book and the Maintenance Standards Book; and a general treatment of sensitivity measurements is included in chapter 6 of this training course. However, the following brief description of the procedure for making one check (band 1, 14 kc, A1 broad) on the AN/SRR-11 is sufficient to give the general idea.

1. Set the reception control (fig. 9-15) to A1 BROAD, the output control to maximum (10), and the tuning dial to 14 kc.
2. Disconnect the antenna simulator (dummy antenna) from the signal generator and connect a short across the input of the antenna simulator.
3. With the add decibles switch in the -10 db position, adjust the gain control for a noise level of -10 db, as read on the output meter. (This is a total of -20 db with respect to 6 milliwatts, or the equivalent of an output level of 60 microwatts, or 0.19 volts across 600 ohms.)
4. Remove the short across the input of the antenna simulator and reconnect the dummy antenna to the signal generator.
5. With the signal generator set for an unmodulated output, tune the signal generator for a maximum indication on the receiver tuning meter.
6. Set the reception control to A1 SHARP, and adjust the receiver freq vernier to produce a beat note of 1000 cycles per second. This condition produces a maximum reading on the output meter.
7. Set the reception control to A1 BROAD.
8. With the add decibels switch in the 0 db position, adjust the signal generator for 0 db reading on the receiver output meter. (This is the equivalent of an output level of 6 milliwatts, or 1.9 volts across 600 ohms.)
9. Under this condition, the signal generator output level (in microvolts) is a quantitative

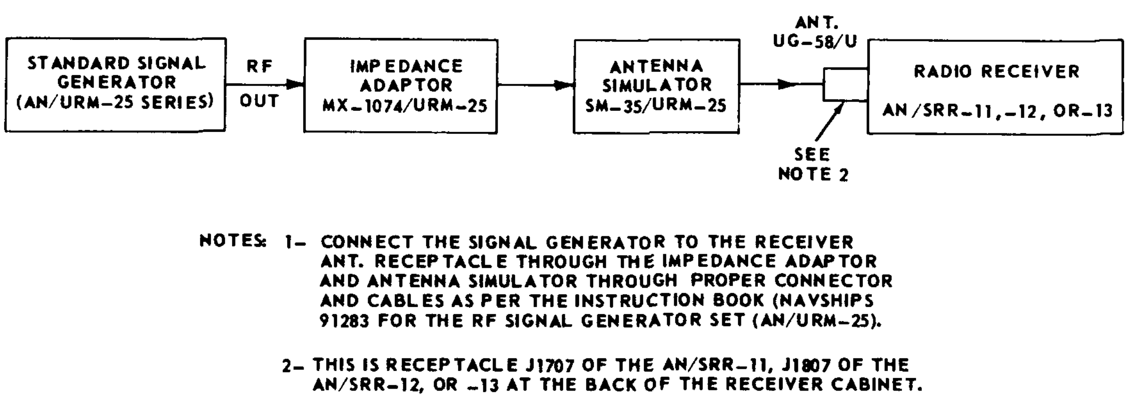


Figure 12-17.—Test setup for receiver sensitivity measurements.

measure of the receiver sensitivity. This value should be checked against the corresponding value given in the tables in the instruction book. For the particular check discussed (band 1, 14 kc, A1 BROAD) the sensitivity should be 4.7 microvolts.

MAINTAINING RADAR EQUIPMENT

Preventive maintenance (normally done by operators of radar equipment) includes the periodic inspection, cleaning, lubrication, checking of brushes, cleaning and tightening of contacts, calibration, and checking of system performance.

The routine maintenance schedule includes daily, weekly, monthly, quarterly, semiannual, and annual checks. In each case the necessary safety precautions must be taken.

The detailed steps to be taken in the preventive maintenance of radar equipment depend, of course, on the particular equipment being maintained. The following preventive maintenance procedures apply to Radar Set AN/SPS-10 which is described in chapter 11, of this course, Common Operating Adjustments.

DAILY CHECKS include checking the echo box ringing time of the transmitter.

WEEKLY CHECKS include cleaning out dust, wiping parts (especially insulators), wiping tubes and checking their seating (including tube clamps), testing spare fuses and replacing any missing spares, and cleaning plastic windows. Other weekly checks include CHECKING AIR FILTERS (a most important check) and making sure that the blowers are running, checking for any arcing in the r-f system, and checking to ensure that the crystal currents are within the correct range (0.4 to 0.6 ma).

MONTHLY CHECKS include such items as checking electrical contacts and the action of interlocks; checking the oil level in the antenna assembly and making sure that the nozzle is clean; lubricating gears; replacing TR and ATR tubes every 500 hours if necessitated because of poor signals or poor recovery time; and listening along the waveguide, r-f system, and antenna for arcing.

QUARTERLY CHECKS are largely of a mechanical nature. Stuffing tubes are checked and repacked if necessary, terminal strips and cables are checked, ferrule resistors and fuses are cleaned, and blown-fuse indicators and dial lights are checked to ensure that they are operative. Other monthly maintenance procedures include such items as replacing tubes missing from tested emergency spares, checking tube pins and sockets for corrosion, checking for corrosion in other places and applying touchup paint as needed, lubrication, checking brushes, on the antenna main drive motor and the slip rings, and cleaning the r-f system and tubes as needed.

The SEMIANNUAL CHECKS include greasing certain points in the antenna well, checking the brushes on the antenna selector switch motor, checking the brushes on the pulse-length switch motor, and oiling hinges and rotors.

ANNUAL CHECKS include a visual inspection of resistors for evidence of overheating, antenna overhaul, synchro and slip ring check, tightening of flange bolts, and certain greasing operations.

The chassis and cabinets are best cleaned with a vacuum cleaner or with clean cloths. A cloth moistened with an approved solvent may be used to clean high-voltage insulators and metal surfaces; the surfaces are finally polished with a dry cloth. Oil and dust must be cleaned out thoroughly, both inside and outside the cabinets. Oil inside a cabinet will usually be caused by a leaky oil-filled capacitor, which should be found and replaced. Oil inside the antenna assembly may be caused by leakage, carelessness in lubrication, or excessive lubrication.

Compressed air or portable blowers may blow dust into relay contacts and into open switches, and should be used cautiously, if at all.

Plastic windows and color filters should be cleaned on both sides with lens tissue or a soft cloth free from abrasive. An approved solvent may be used when needed. Care should be taken to avoid scratching because the plastic is relatively soft.

Air filters are used in the cabinet, modulator, and transmitter. The filters must be cleaned periodically (at least monthly). The accumulated dust is removed by hosing the cleaner with hot water or allowing water to float through the cell from the clean side. The cell is then washed in a solution of hot water and washing compound, rinsed, and allowed to drain. The cell is then recharged by immersion in light machine oil and allowed to drain for at least twelve hours. An alternative method of recharging is to spray the cleaner with a hand-operated spray gun until the cleaner has received as much oil as it will take without dripping.

Ceramic insulators should be kept clean to prevent leakage and possible arc overs. If wiping with a clean cloth is not sufficient, a cloth moistened with an approved solvent may be used. The insulator is then polished dry with another clean cloth.

Ferruel resistors and fuses should be removed from their clips, and corrosion and dirt removed from the components and the clips. To ensure correct replacement they should be removed and replaced one at a time, FIRST TURNING OFF ALL POWER. A clean cloth moistened with an approved solvent will usually be sufficent, but in some cases crocus cloth or fine sandpaper may be required.

A clean dry cloth (which will not leave any lint) will usually suffice to remove dust from tubes. Great care must be exercised in cleaning tubes that operate at high temperature because a layer of dust interferes with heat radiation and raises the operation temperature of the envelope. When cleaning is completed, the tubes must be inspected to see that they are properly seated and all clamps locked.

Both sections of the TRANSMITTER INTERLOCK SWITCH should be inspected. These ordinarily will not required attention unless a switch is opened under load, such as during conditions of extreme shock or when the unit is opened when the power is on. Contacts should be cleaned with crocus cloth or fine sandpaper. A burned switch should be replaced.

The CABINET INTERLOCKS are of the microswitch type and require no servicing except replacement in case of failure.

The GROUNDING SWITCH in the modulator power supply is a safety switch and normally will receive very little use. When necessary its contacts may be cleaned with corcus cloth.

RELAYS and RELAY CONTACTS should be cleaned periodically. Any dirt found should be removed and the contacts inspected. If the contacts are clean and bright and the relay is functioning normally, it should be left alone; but if the contacts are dirty or pitted, they should be cleaned. The use of carbon tetrachloride or alcohol for cleaning contacts is not satisfactory because they leave an insulating film. Other unsatisfactory methods include the use of a file (it leaves a rough surface that impairs the wiping action), crocus cloth (it leaves a rough surface and a coating of rouge), emery cloth (it leaves emery embedded and causes arcing), and sandpaper (it leaves sand particles and causes arcing). The use of a burnishing tool is the accepted method.

It is extremely important to maintain electrical contacts in good condition because faulty electrical contacts can cause equipment failure at a critical time.

ANTENNA SLIP RINGS should be inspected once a year during overhaul. If dirty, they should be cleaned with a cloth pad on a stick; if extremely dirty or oxidized, they may be burnished with crocus cloth or very fine sandpaper sufficiently worn to remove loose sand particles. DO NOT use emery cloth on slip rings.

In general, all R-F CONTACT SURFACES and the interiors of resonant cavities should be kept as clean as possible to ensure maximum performance. A vacuum cleaner may be used to remove loose (dust) particles. Where the surfaces can be reached, as in TR and ART cavities, they should be cleaned with lens tissue moistened with an approved solvent and then dried carefully with clean tissue.

CORROSION SPOTS on metal surfaces should be cleaned and touched up with suitable paint. The cause of the corrosion should be carefully investigated and steps taken to prevent its recurrence. Possible causes may be open heater resistors or defective thermal switches.

LUBRICATION is an extremely important part of preventive maintenance. Insufficient lubricant in the antenna will eventually cause failure of the equipment. Routine lubrication at these points as well as at other less vital points is indicated in the lubrication chart in the instruction book.

BRUSHES are used only in the modulator and antenna. The two modulator brushes are in the pulse-length switch motor; they should last almost indefinitely because of their light service. The antenna brushes receive moderate service and must be checked more frequently.

Certain ROUTINE MECHANICAL CHECKS are necessary. Terminal strips should be cleaned and terminal screws checked for tightness at regular intervals. It is important not to overtighten terminal screws, but because they sometimes work loose, they should be checked.

Cables should be inspected for looseness or damage at unit entrances, and at any other point in a run where the cable is subject to damage from heat or other abuse. Cables showing signs of damage should either be rerouted or suitably protected. Particular attention should

be given to coaxial cables, which are easily damaged by dents or sharp bends.

Certain ROUTINE ELECTRICAL CHECKS are also necessary. Blown-fuse indicators are checked by removing and replacing the fuses, one at a time, with the power on. INSULATED FUSE PULLERS MUST BE USED for all fuses held by fuse clips, and care must be taken to avoid injury from shock. With the circuit energized, the indicator lamp should not glow when a good fuse is in place but it should glow when the fuse is removed. If the operation is abnormal, corrective maintenance will be required.

When a dial lamp burns out, it must be replaced.

The echo-box ringing time is very important, and a check should be made during each day of operation. The check will be made during each operator's watch if so prescribed. This check along with mds (minimum discernable signal) will enable the ET to maintain, and ensure peak performance of the system, and minimize system failure by indicating faulty operation in its early stages.

The magnetron is the heart of most radar sets; and, although it is capable of generating high-pulse power, it can be damaged easily by careless handling. A damaged magnetron can be costly both in safety and in money, and therefore proper handling must be emphasized.

The magnetron shipping container is necessarily bulky in order to protect the tube during shipment and storage. There are two principal reasons why the magnetron must be carefully protected. Excessive vibration or shock can damage the tube, particularly the cathode portion, which is relatively long and suspended only at one end. Also, the magnetic properties of these tubes must be protected during shipment and storage as well as during the time they are in use. If these tubes are not properly spaced in storage (by means of one container with another) the magnetic fields may interact to the detriment of both permanent magnets.

When it becomes necessary to transfer a magnetron from its container to a radar transmitter, care must be exercised to make certain that the parts that are normally protected by the shipping container are not injured in handling. Some of the larger magnetrons (tube and magnet) may weigh as much as 70 lb; therefore handling them may be an immense chore.

The size and weight of some magnetrons may lead one to assume that they are rugged; however, this is not the case. For example, if the heater terminal is struck during handling, it is possible that the cathode may be moved sufficiently (a few thousandths of an inch) to cause permanent damage.

Magnetrons (the integral magnet type) must be kept away from iron or steel (tools, decks, tables, etc.). Read and follow the instructions on the caution label.

Additional precautions may be summarized as follows:

1. DO NOT USE STEEL WOOL for cleaning a magnetron because the strong magnetic field may cause the steel particles to stick to the insulated portions of the tube.
2. Do not write on the ceramic parts of a magnetron; for example, a pencil mark could cause arcing and a permanently damaged tube.
3. When water is used as a coolant, be certain that all water is drained before the tube is stored in a compartment that will be subject to freezing temperatures. If water freezes in the tube, it will very likely be ruined. (Be sure to wipe the moisture from the insulated portions of any magnetron that has been stored in such a compartment before it is put into use.)
4. The oil required in the cathode bushing of some magnetrons must be kept free from dirt and moisture. Use only the oil specified in the instructions.
5. Tubes to be returned to the manufacturer should be handled carefully and packed according to instructions; consult the latest ESO publications for information on the disposal of magnetrons.

MAINTAINING RADIAC EQUIPMENT

Station personnel may perform limited maintenance of radiac equipment, but such work is restricted to repairs that DO NOT AFFECT CALIBRATION. Radiac repair is accomplished by technicians at a radiac repair facility.

Currently, most of the difficulty with shipboard radiac equipment seems to be caused by dead batteries, electronic circuit failure, corroded battery compartments and physical damage, of which corrosion appears most frequently and proves most serious.

CHAPTER 13

MAINTENANCE PROCEDURES AND TECHNIQUES, PART II

CORRECTIVE MAINTENANCE PROCEDURES

To perform effective corrective maintenance the ET must have a good working knowledge of the basic principles of electricity and electronics. The only way to acquire this knowledge is by diligent study. The ET must also be thoroughly familiar with the theory of operation of the equipments that he must service. A knowledge of the theory of operation can be acquired through a study of the "Theory of Operation" section (generally, section 2) of the equipment instruction book. In the new technical manuals, a different procedure will be followed. This knowledge should be broadened to include other equipments at the earliest opportunity. As a matter of fact, ETs are generally rotated on the various electronic equipments so that their knowledge will be broadened and they will therefore be more valuable to the fleet.

Skill in the use of test equipment (and handtools) is also necessary for effective corrective maintenance. Skill in the use of test equipment comes with practice and with careful study of the instruction book that comes with each piece of test equipment. The ET should take advantage of every opportunity to learn more about every type of electronic test equipment used aboard ship. The ability to use test equipment effectively is an absolute must for every well-trained ET.

Chapters 6 and 7 of this training course introduced the prospective ET to some of the more common test equipments. Additional valuable information (both on test equipment and methods of troubleshooting) is contained in Test Methods and Practices Handbook, NavShips 900 000.103. A list of the various electronic test equipments (also troubleshooting methods) is included in the Electronics Installation and Maintenance Books, NavShips 900,000.

This chapter treats, in a general way, some of the corrective maintenance procedures used for the various types of electronic equipment. Detailed procedures for troubleshooting each piece of electronic equipment are contained in the instruction book of that particular piece of equipment. One of the most valuable aids in the instruction book is the troubleshooting chart. These charts will be discussed under the various types of electronic equipment.

Tests (opens, grounds, and shorts) and measurements (currents, voltage, resistance, frequency, power, etc.) enable the technician to diagnose troubles so that repairs may be made. In many instances tests and measurements will indicate conditions that may be corrected before an actual breakdown occurs. Thus, tests and measurements (particularly measurements) are important both in preventive and corrective maintenance.

The purpose of any type of electronic test equipment is to measure accurately certain circuit values or to indicate certain circuit conditions. Each of these measurements or indications is used to determine the operating condition of electronic or electrical equipment. The accuracy with which measurements are made depends on the type of instrument used, its sensitivity, its rated accuracy, its useful range, and the care that the technician uses in making the measurement.

The exact procedure for making tests and measurements is given in the technical manuals (instruction books) that accompany the various electronic equipments.

It should be emphasized that the mere taking of measurements means little unless they can be properly interpreted. For example, the presence of a voltage across a grid resistor in an audio amplifier would mean little to an ET unless he could interpret this in terms of a possible leaky coupling capacitor. In this connection, the necessity for a knowledge of basic circuit operation must be emphasized.

Before any attempt is made to interpret the results of measurements, an understanding of

how the equipment operates should be acquired by a careful study of the applicable technical manual or instruction book.

The actual voltage, resistance, and current measurements that should be obtained are indicated in the circuit diagrams, charts, or in the maintenance standards books. The same is true of waveform measurements. Any deviation from the standard values (beyond the tolerance limits) means that some component is not doing the job that it should. By applying effect-to-cause reasoning, the defective component may be located. This is, of course, a job for a skilled technician.

According to the "quals," the prospective ET 3 must be able to localize equipment casualties to components or subassemblies and to make the repair by replacement of subassemblies or parts. However, it is conceivable that under certain circumstances, especially on smaller vessels, the ET 3 may have to effect the entire repair. In any case, the "quals" spell out only the minimum qualifications for advancement in rating, and the prospective ET 3 should in no way restrict his knowledge or his ability to make repairs.

There are numerous ways to isolate a fault to a component of a system, depending on the type of equipment. The technician must, first of all, know what each component does before he can know that it is not functioning properly.

Assume, for example, that the display on a certain radar repeater is faulty. The trouble could be in the repeater or it could be in one of the circuits that feeds into the repeater. If the other repeaters are working properly, it is probable that the trouble is in the repeater having the faulty display or in its power supply or in the transmission lines or switching system.

The best way (the most economical in time and effort) to isolate a fault is by using a logical troubleshooting method.

TROUBLESHOOTING

Good troubleshooting is not a talent with which a person is born. It is, however, a skill that can be acquired by anyone with a suitable electronics background. One can become a good troubleshooter if he has:

1. Sufficient electronic knowledge to learn, or to be taught how an equipment works.
2. Suitable skill in reading and interpreting data contained in the equipment's technical manual.
3. Suitable skill in operating test equipment and interpreting test readings.
4. Has learned how to troubleshoot in a logical manner.

Logical troubleshooting does not recognize "easter-egging," "cook-booking," or "trial-and-error" methods. The "easter-egger" makes unsupported guesses; the "cook-booker" looks for trouble-locating clues in the trouble chart; and the "trial-and-error" technician starts at one end of the equipment and works toward the other. If any of the three finds the trouble in a reasonable length of time, he is lucky. An average size equipment will have 100 circuits, 700 electronic parts, and hundreds of wires and terminal boards and/or connections. A large size equipment may have 1000 circuits, 7000 electronic parts, and thousands of wires and terminal connections. Finding the one bad or partially bad part, wire, or connection among hundreds or thousands is not easy to do by illogical methods.

Logical troubleshooting is a time-proven procedure used by all accomplished technicians. Most of them have applied the procedure so often that they no longer pay attention to its fine points. Through habit and years of experience they may have forgotten its specific details, but the procedures are there and have remained the same.

Probably no two technicians would explain the procedure alike, but all would agree that logical troubleshooting consists of a series of sequential steps based on valid electronic decisions that systematically narrows the trouble down to the faulty part. Some would list the procedure in three or four steps others would count a dozen, fifteen, or more. Regardless of the number, the principle would be the same. Six steps have been chosen as the easiest method of learning and applying this procedure. The steps in their sequential order are:

1. Symptom recognition
2. Symptom elaboration
3. Listing the probable faulty functions
4. Localizing the faulty function
5. Localizing the faulty circuit
6. Failure analysis

Symptom Recognition

The first step in any troubleshooting problem is recognition of a trouble indication. Recognizing a trouble condition in an equipment is not always easy to do since all conditions of less

than peak performance are not always apparent. Lack of targets on a scope, timing error in a loran set, and a decrease in signal-to-noise ratio in a receiver are just a few of the hundreds of examples occurring throughout the Navy. Each of these is a trouble symptom that requires recognition and elimination.

There are many ways in which the existence of a trouble can be detected by a technician. The obvious troubles will undoubtedly be reported by the operator. These usually include complete or almost complete malfunction of the equipment. Troubles that are not easily noticed are those that cause a gradual decrease in equipment performance. For example, a 125-mile radar that is reaching only 105-miles, a 100-watt transmitter that is putting out only 87 watts, or a multimeter that provides readings that are 10% off, are equipment faults that are difficult to recognize because there are no visible or audible indications (built-in) that say they exist.

Since a ship must depend on full-performance equipment the hidden trouble symptoms must be found, the cause of the trouble located, and the repair made. If the technician makes a point of looking for them every time he touches an equipment most of the decreasing performance symptoms can be easily recognized. Often he can compare the performance between two similar equipments. He can actually make the Performance Standards sheet checks contained in the POMSEE program. By using the POMSEE books, he can verify any change in performance since the last time he tuned, calibrated, or aligned the equipment. Also while troubleshooting, he may look for and probably find symptoms that signify decreasing performance and future breakdown if left unnoticed. Trouble symptoms can be recognized if the technician will only look for them.

Symptom Elaboration

Breaking out test equipment and equipment prints and proceeding headlong into troubleshooting on just the original identity of a trouble symptom is a very shaky premise. It could also be an unnecessary expenditure of energy. A dead scope, a hum in a receiver, a zero reading on a panel meter, or a missing transmitter pulse, by itself, is not sufficient identification of a trouble symptom. There is a tendency among less efficient technicians to attempt a solution of a troubleshooting problem before they have completely defined it.

The procedures involved are dependent upon the available aids designed in the equipment and the nature of the original symptom. The aids include front panel controls and built-in performance measuring indicators. Additional information can be obtained about any malfunction as the result of a systematic front panel check. If the technician has a fair knowledge of how the equipment works, manipulation of appropriate controls and switches and corresponding checks of equipment meters and scopes will reveal to the technician how the trouble is affecting the entire equipment. From these clues he is able to narrow down the probable areas of the equipment that could contain the trouble.

Listing The Probable (Faulty Functions)

The third step requires that the troubleshooter make an educated guess as to the probable cause of the trouble. From the elements of the trouble symptom, as he has identified it, he determines its most logical locations. Locations are to be confined to the major subdivisions (major or functional units) of an equipment. Educated guesses are made from the knowledge of how the equipment works and a study of the equipment's functional block diagram.

For example, using a malfunctioning radar that has no targets on the PPI but the transmitter and modulator indications read good, the educated guesses could include: (a) remote indicator unit, (b) receiver unit, (c) low-voltage power supply, and (d) duplexor. Making an educated guess that a tube is bad (just because the greater percentage of all equipment troubles are caused by bad tubes) is not acceptable. The purpose here is to use valid reasoning to isolate all probable, technically sensible functional areas which may contain the trouble. It may well be that the specific trouble is a bad tube, but wholesale tube substitution takes a lot of time and quite often introduces additional troubles, particularly in those circuits that operate close to critical tolerances.

Even the accomplished technician may not be able to list all the functional units that are probable sources of the trouble. However, with the exception of a very obvious trouble, a multi-unit equipment will have many functional units that are probable sources of a trouble.

Localizing The Faulty Function

In this step one of the educated guesses must be selected for testing. It is not necessarily the one that was thought of first nor the one that past experience suggests as being the most attractive. The selection of the functional unit to be tested (or verified) first should be based not only on priority of validity but also on the difficulty in making the necessary tests. Under some circumstances, a troubleshooter might elect to test the second best educated guess rather than the first because the latter might involve testing difficulties that should be initially avoided or require tampering with circuit parts that might later prove to be unnecessary. Like all the others, this step in the troubleshooting procedure places emphasis on common sense thinking rather than the resultant action.

After selecting the order in which the listed units will be checked, the troubleshooter proceeds to verify his first selection. This check normally is made at the output test point of the suspected unit. The test equipment reading is compared with the desired signal contained in the technical manual. No output is relatively easy to recognize. A distorted or nonstandard output, however, should be carefully verified before arriving at a technical conclusion.

If the technician does his mental work properly, manual work in gaining access to test points and using the test equipment can be limited to a bare minimum. This procedure is opposed to trial-and-error methods where the technician searches from point to point with test prods, hoping to locate the faulty test reading that identifies the trouble. Not only does the illogical technician waste valuable time, but his unwillingness to rely on his technical knowledge indicates that he will be very lucky if he finds the trouble.

Upon completing the verification of the propable faulty unit selected, the technician will have arrived at one of several conclusions. The test may verify that this is the unit in which the trouble lies; or that the trouble could be in this unit plus another unit(s) from which it receives signal or control voltages; or that the trouble is not in this unit at all; or that the output looks suspicious and further verifying tests need to be made.

Whatever the conclusion, the technician has discovered information that can be used to substantiate or eliminate suspected units or provide evidence for adding another. Tests of suspected unit outputs are continued until the single faulty unit is identified. At that point, the technician has narrowed down the trouble to a fraction of the total number of circuits and parts in the equipment. If at this time the proper procedure was carried out the search can be confined to the functional area isolated. NOTE: There are some equipments such as communications receivers, that cannot be easily divided into functional units. If this type of equipment is involved, steps 3 and 4 above, can be eliminated from the overall troubleshooting procedure.

Localizing The Faulty Circuit

After the faulty unit has been isolated, the next step is to identify the faulty circuit. The same narrowing-down procedures are used here as before. The unit is mentally subdivided into circuit groups by function, and valid technical reasoning is employed to select those that might probably contain the trouble. Using this procedure the technician can find the faulty circuit without going through the unnecessary time-wasting chore of test-point to test-point checking from one end of the unit to the other.

The technician works from the servicing block diagram of the unit. He then applies the information obtained from the preceding steps regarding the nature of the trouble. In narrowing down the trouble to a single functional group of circuits, the process used is called "bracketing." In this process brackets are placed, mentally or in pencil, around the area in which the trouble lies. Initially, a bracket is placed at the input(s) to the units that are known to be good and at the output(s) known to be bad. As each deduction is made and verified by a test, the input or output bracket is moved to the next point in the block diagram where the test was made. In this manner the closing brackets systematically narrow the fault to a single circuit.

In selecting a point on the servicing block diagram to which one of the brackets is to be moved, the technician must consider two things: (1) the faulty characteristics of the improper output signal and (2) the types of signal paths contained in the unit. The waveshape of a signal contains characteristics—voltage, time, bandpass, noise content, frequency, etc.—that can be measured or observed. When these characteristics are in accordance with the designed

standards, the signal is considered to be good. Bad signal characteristics that are improper can reveal clues that will help to identify a circuit group whose function is to originate or control that portion of the waveshape. For example, the output of a unit is supposed to be a sawtooth waveform with six pulses, equally spaced on its slope. If the pulses are there but the slope is insufficient or improper, the sawtooth generating and shaping circuits would be suspected. If the proper slope is there but there is insufficient number of pulses, the pulse generating or controlling circuit groups may contain the trouble.

Types of signal paths contained in the unit are the other items to be considered before moving a bracket. There are four general types: linear, switching, convergent/divergent, and feedback. In a linear signal path, the signal is processed through circuits that are connected in series. When identification of the faulty circuit group is difficult or impossible, brackets can be moved to successively smaller half-points in the linear string. Signals from two or more circuit channels that meet at a common point or a signal that leaves a common point into two or more channels are examples of convergent/divergent paths. Moving a bracket to the common point (after making the appropriate test) will separate the bad from the good signal paths. In the same manner, a test and bracket at the point where signal paths are connected by a switch will reveal the same information. The remaining type (feedback loops) provides a means of bracketing a group of circuits in the narrowing-down process.

There are no hard-and-fast step by step procedures in bracketing. But there are some realistic general rules.

1. Examine the characteristics of the faulty output to determine the circuit group function that either generates or controls the improper characteristic.

2. Study the servicing block diagram to determine the least number of bracket moves that will isolate the faulty circuit. Such moves will be dependent upon the types of signal paths contained in the unit and the electronic functions of circuit groups that may be responsible for distortions contained in the unit's output.

3. Move only one bracket at a time after verifying the suitability of the signal by making a test.

4. When the test does not reveal sufficient information for a valid bracket move, make another educated guess.

5. The determination of which bracket to move is dependent upon circuit configuration within the unit and the smaller number of circuits that will be enclosed.

The servicing block diagram can serve as the instrument for the completed bracketing process. In some cases it may be necessary to refer to a schematic diagram for bracketing or testing information. In any event there is sufficient diagram information available in the technical manual to support the bracketing procedure and preclude the wastefulness of unreliable circuit to circuit checking. This step is completed when the technician has isolated the trouble to a single circuit and verified that the output of this circuit is the cause of the distortion read at the output of the unit.

Failure Analysis

The troubleshooting procedure thus far has narrowed the trouble to a single circuit consisting of a tube (or transistor) and a few electronic components. If there is no output from the circuit, it may be permissible to resort to rote testing of tube pin numbers. However, such checks can be minimized if there is an output that can be examined for distortions that will reveal the circuit part that is most likely at fault. Quite often the waveform will identify the malfunction to be in the grid, cathode, plate, or screen portion of the circuit. Such a study should be made before any of the parts are checked.

When the faulty part has been identified, it should not be replaced until the technician can SUBSTANTIATE THAT IT IS CAUSING THE ACTUAL TROUBLE. A suspected open resistor, shorted capacitor, detuned coil, or weak tube may not be the reason or the only reason causing the faulty output of the circuit. If the technician replaces the part without an adequate technical reason, he may (when replacing the part) not have cured the trouble and he may yet cause further trouble. ANALYZE THE FAILURE BEFORE MAKING THE REPAIR.

It can now be seen that the six-step troubleshooting procedure is designed to isolate a trouble in an orderly manner. Success in using the procedure is dependent upon the technician's knowledge of electronics, the equipment under test, and his skill in using the technical manual and test equipment. The process is no more

complicated than the ability to subdivide an equipment into progressively smaller functional areas, such as functional units into functional circuit groups, to a circuit, and finally a part or an adjustment within the circuit. It is the only logical way to troubleshoot any equipment, and it is more reliable and faster than any other method.

TROUBLESHOOTING RADIO EQUIPMENT

Maintenance personnel must be prepared to repair and align units that have failed in operation. The source of the trouble must be located, the defect remedied, and the equipment restored to optimum operating condition. The following paragraphs (concerning radio and radar equipment) describe the theory of localization of faults and troubleshooting procedures as contained in the manufacturer's instruction books. Also contained therein are detailed instructions for the troubleshooting and repair of the various units of these equipments.

Maintenance personnel must try to find the source of the trouble causing the equipment failure, particularly when the trouble is a recurrent one. The recurrence of a fault usually indicates that the EFFECT, not the CAUSE, has been remedied.

Keep in mind throughout this study, that by far the largest section of the average instruction book is the one devoted to corrective maintenance (troubleshooting). This is the section written especially for the ET and when used with the six-step logical troubleshooting procedure described above can be for him the most valuable part of the book. The section on the theory of operation, however, is also very important and should be studied with care.

Transmitters

Corrective maintenance in radio transmitters follows much the same pattern as in radio receivers, except that more indicators are likely to be involved in the use of the system troubleshooting chart. Consider for example, Radio Transmitting Sets, AN/SRT 14, 15, 16.

The following test equipment is required:

1. Multimeter (ME-25A/U or AN/PSM-4 series).
2. Oscilloscope (OS-8/U).
3. Frequency Meter (AN/USM-29).
4. Receiver (AN/SRR-11, 12, 13 series)
5. Audio oscillator (TS-382C/U).
6. Dummy Load (DA-91A/U).
7. R-f Signal Generator (AN/URM-25B).
8. Resistance Bridge (ZM-11A/U).
9. Radio-Frequency Bridge (Navy type 60094).
10. One-megohm, linear taper potentiometer.

Like most transmitters, this equipment operates at high voltages that are dangerous to life. Therefore, safety regulations must be observed at all times. Do not change tubes or make adjustments inside the equipment when the high voltage is on; do not use the "battle short" for bypassing interlocks. Never measure potentials in excess of 600 volts by means of flexible test leads or probes.

The manner in which this equipment operates or fails to operate often indicates the source of trouble. A knowledge of the control circuits (see chapter 9 of this training course) is most important for the localization of faults. It is, of course, necessary for the ET to become familiar with the simplified power and control schematic diagrams in the instruction book. The sequence of operations that result in the establishment of a carrier frequency is accomplished by visual panel indications.

The order in which the visual indications appear is shown in the system troubleshooting chart (in the instruction book), a small portion of which is included in figure 13-1. If the proper sequence of events does not take place, trouble is indicated.

The heavy blocks tell what is to be observed, and the heavy arrows between these blocks point in the direction of the sequence of indications that should be obtained (when the transmitter bay is operating properly) from the time that main power is applied to the time that the carrier is keyed on the air. Indications of proper operation are listed in the general order in which they occur. Each indication along the heavy path is evidence of proper operation only if all preceding indications have been obtained. However, some of the indications may occur simultaneously.

If the proper indication is not obtained, the lighter blocks (to the left) name the unit (or units) in which trouble may exist. The ET should then refer to the portion of the instruction book that gives troubleshooting information for that particular unit. If the proper indication fails to occur, the ET should first check the indicating component.

A dummy load (type DA-91/U) may be used during tests and maintenance procedures to

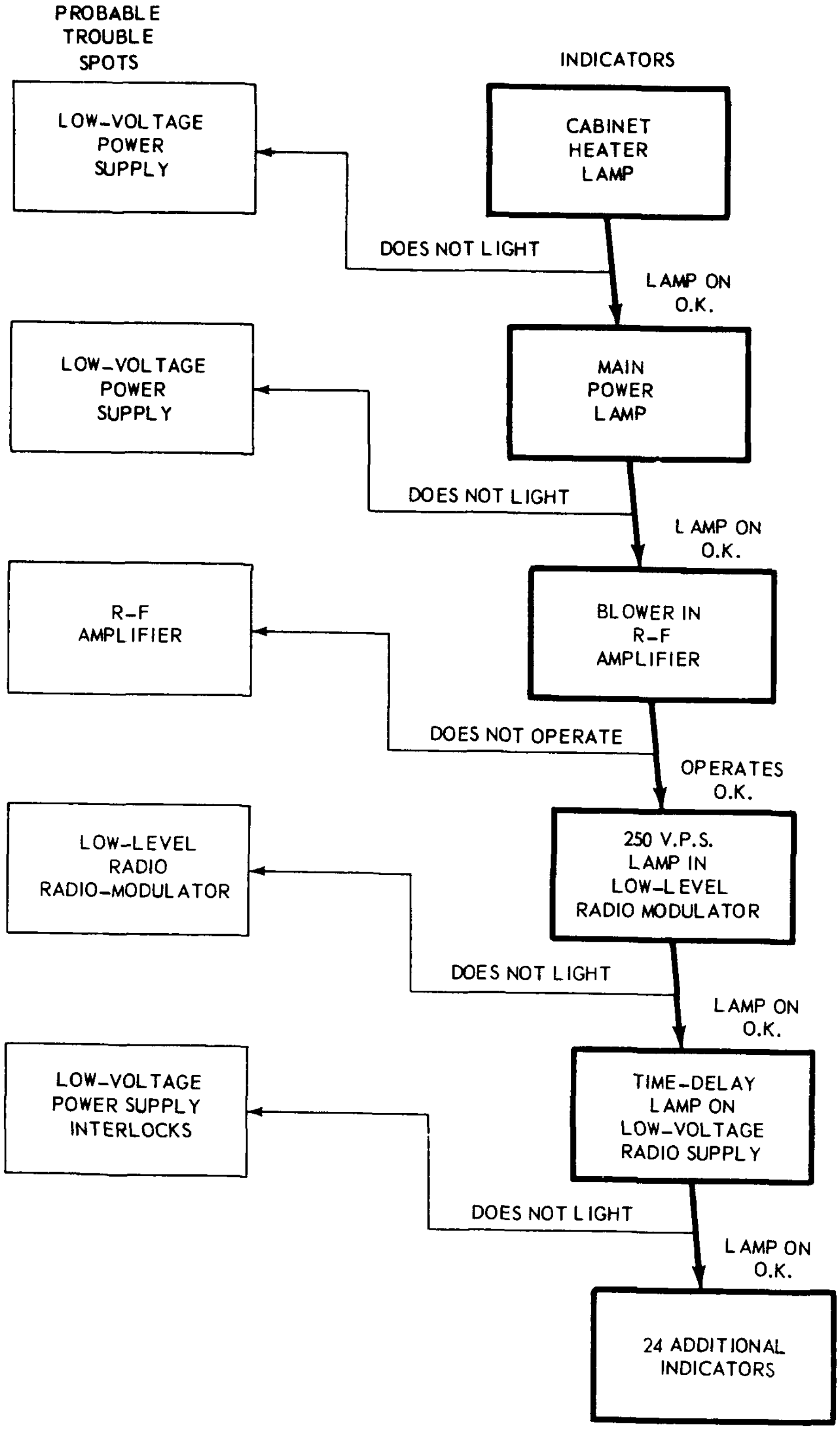


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Figure 13-1.—First five indicators in the AN/SRT-14, 15, 16 troubleshooting chart.

avoid radiating an r-f carrier from the antenna.

Receivers

The following information, condensed from the corrective maintenance section of the instruction book for Radio Receiving Sets AN/SRR-11, 12, and 13, will give a general idea of the procedures used in performing corrective maintenance on radio receivers. Of course, the instruction book for the particular receiver being serviced must be used in every instance.

The following test equipment is needed:

1. Multimeter (AN/PSM-4, TS-352/U series).
2. Electronic Multimeter (ME-25/U series).
3. R-f Signal Generator (AN/URM-25B), with the necessary impedance adapter, antenna simulator, and test lead having isolating capacitor.
4. Audio Oscillator (TS-382C/U)
5. Heterodyne Frequency Meter (LM series).
6. Oscilloscope (OS-8/U series).
7. Tube Tester (TV-10/U series).

When trouble occurs, the first step is to establish in which assembly the fault exists. The faulty assembly can then be replaced if a spare one is available, or repaired if there is no spare assembly.

Most of the assemblies are divided into subassemblies, many of which plug into the assembly. Each plug-in subassembly contains a subminiature electron tube and associated parts.

Plug-in subassemblies are of two types: plug-in boards and plug-in units. The plug-in boards are located in the antenna, r-f mixer, and oscillator assemblies; the plug-in units are in the first i-f, second i-f, audio, BFO, and crystal-calibrator assemblies. The tuning dial and filter assemblies do not contain electron tubes.

The procedure given in the troubleshooting chart in the instruction book will permit the ET to quickly and systematically check the functioning of the radio receiver by observation of the indicators that are built into the equipment.

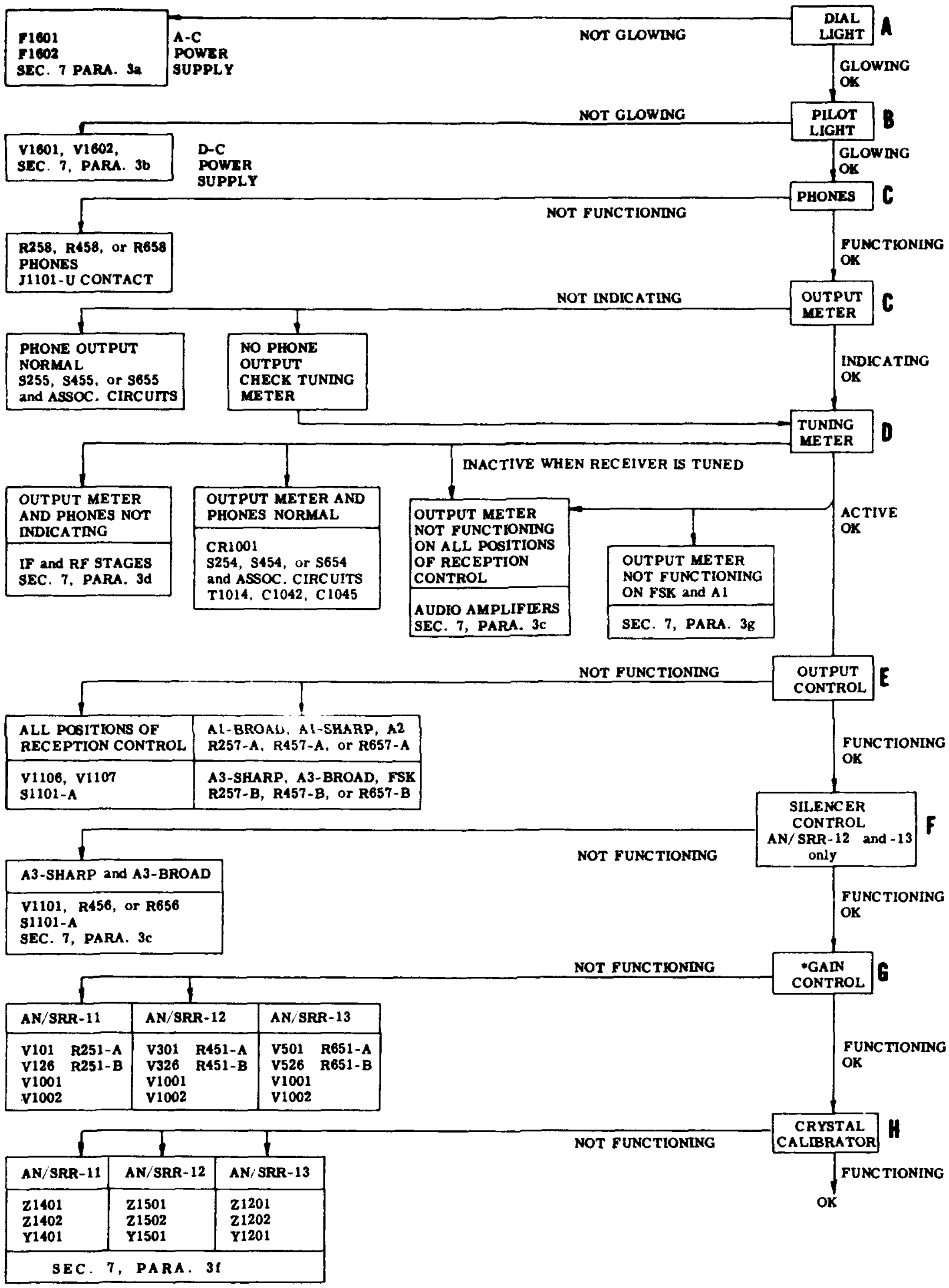
Two of the indicators (the tuning meter and the output meter) check the signal circuits; the other two indicators (the pilot light and the dial light) check the power circuits. If the technician follows the exact procedure given in the troubleshooting chart, he can localize the trouble to a subassembly or system. After the trouble has been localized to a subassembly or system the detailed troubleshooting procedure (also given in the instruction book) may be used to locate the defective component (tube, resistor, capacitor, etc.).

The troubleshooting chart from the instruction book is reproduced in figure 13-2. When trouble occurs, the chassis should be inspected for charred insulation, discoloration of parts, leakage of potting compound, or other indications of abnormal operation. If the parts appear normal, the ET then proceeds to track down the trouble by the use of the troubleshooting chart, as follows.

1. Turn the power switch ON and check the dial light. If the light glows, the power input and power transformer primary circuits are operating. In this case, move on the next step, B. If the dial light does not glow, switch the lamps control to the SPARE position; if the dial light still does not glow and the receiver is dead, then replace the fuses (F1601 and F1602) located in the bottom of the power supply assembly. If this does not cure the trouble, the ET should then consult the detailed troubleshooting procedure included in the instruction book.

2. Check the pilot light. If the light glows, the d-c power supply is operating. In this case move on to the next step, C. If the pilot light does not glow, replace it if it is burned out. If the light still fails to glow, replace V1601 and V1602 in the power-supply assembly. If these measures fail, consult the detailed troubleshooting procedure.

3. Check the output meter and phones while attempting to tune in a signal. If the output meter and phones BOTH give an indication of signal, then the receiver is operating, but other associated devices such as the crystal calibrator or tuning meter may not be operating. For a more thorough check, move on to the next step, D. If only one of the indicators (the output meter OR the phones) gives an indication of signal, then the trouble lies within the immediate circuits of the other. This trouble can be localized by taking resistance measurements of the faulty circuit. Refer to the appropriate schematic diagram. If the output meter AND the phones BOTH fail to give an indication of signal then move on to the next step, D.



*This control is active only on the A1 and A2 positions of the Reception Control.

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Figure 13-2.—Troubleshooting chart for Radio Receiving Sets AN/SRR-11, 12, 13.

The same general procedure is followed for six more steps, as indicated in the trouble-shooting chart.

TROUBLESHOOTING RADAR EQUIPMENT

The localization of trouble in an equipment as complex as a radar set (for example, Radar Set AN/SPS-8A) demands an orderly and systematic approach if the trouble is to be located and corrected as quickly as possible. To this end, the troubleshooting procedure should be an attempt to localize the trouble to a particular unit or circuit. This is usually accomplished by a process of elimination. The ET must take time to analyze the trouble and consider the possible sources before beginning to make actual physical or electrical checks on the equipment (use the six step logical trouble-shooting method previously described).

Use should be made of the equipment oscilloscope (monitor scope) to help localize troubles. There are also test points throughout the equipment that afford readily accessible voltage and waveform checks. The corrective maintenance section of the instruction book includes voltage tables, troubleshooting charts, pictures, and circuit diagrams, all designed to make troubleshooting as easy as possible for the ET. The use of the instruction book is a must.

In the case of Radar Set AN/SPS-8A, a large number of troubleshooting charts are included in the instruction book. The first chart covers system troubleshooting. Following this, there are unit and sub-unit charts on the power systems, the synchronizer, the trigger amplifier, the modulator, and so forth; actually, there are 17 troubleshooting charts in all.

The following test equipments are needed:

1. Multimeter (AN/PSM-4 or TS-352/U series)—used for general-purpose testing.
2. Synchroscope (AN/USM-24)—used to check waveforms.
3. Electronic Multimeter (ME-25/U series) —used for general-purpose testing.
4. 30-mc Signal Generator (AN/URM-25 or 26 series)—used for checking receivers.
5. 39-mc and 60-mc Sweep Signal Generator (TS-452/U series)—used for checking receivers.
6. 3400-3600-mc Signal Generator (AN/URM-61A)—used for checking AFC and minimum discernible signal.
7. Crystal Checker (TS-268 E/U)—used for checking receiver crystals.
8. Dummy Director (Mark 1 Mod 3)—used for checking servo systems.
9. Ammeter—used for measuring amplidyne outputs.
10. Gunner's Quadrant (Mark 6 Mod 1)—used for checking antenna level.
11. Resistance Bridge (ZM-11A/U)—used for checking sine and cosine potentiometers.
12. Power Bridge (TS-295 B/UP)—used for transmitter power measurements.

The system troubleshooting chart for Radar Set AN/SPS-8A is shown in figure 13-3. This chart is much the same as those discussed under radio receivers and transmitters. However, it is a SYSTEM troubleshooting chart. If a system defect is indicated the ET must then use the tables (actually, individual trouble-shooting charts) indicated on the left of the figure. As has been mentioned, there are 17 troubleshooting charts in all. The ET will find the overall servicing block diagram a great help when he uses the system troubleshooting chart.

TROUBLESHOOTING TECHNIQUES FOR MINIATURE COMPONENTS AND DEVICES

The use of transistors, crystal diodes, and other semiconductors in Naval electronic equipments is constantly increasing. Because of its versatility, the transistor is used in amplification, modulation and demodulation, and other electronic circuitry applications. Its miniature dimensions make the transistor particularly suitable for use in unitized and modular constructed equipment. For the same reason—miniaturization and compactness—troubleshooting in equipment containing transistors is made more difficult. Because of these developments, procedures relating to the servicing and testing of semiconductors are covered in more detail in this chapter and chapter 6 of this training course.

The successful installation, repair and maintenance of electronic equipment, especially equipment using transistors, has raised many questions concerning proper servicing procedures and troubleshooting practices that previously have been used in electron-tube circuitry.

Transistors perform many of the functions of electron tubes. It will therefore be instructive to compare these devices.

1. In a tube, the cathode is the source of electrons and electrons constitute the current carriers. In a transistor, the emitter is the source of electrons or holes and these constitute

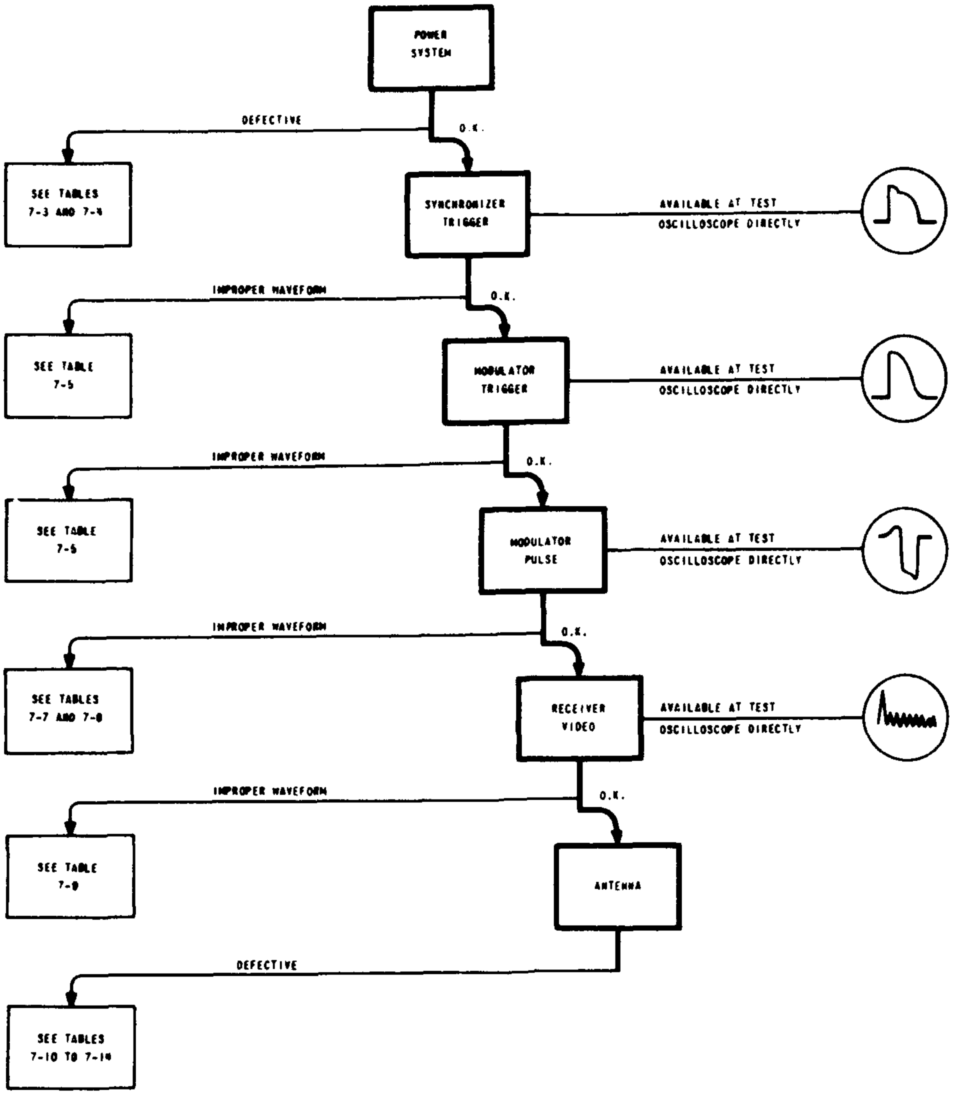

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Figure 13-3.—System troubleshooting chart for Radar Set AN/SPS-8A.

the current carriers. Thus the emitter may be compared to a cathode (figure 13-4).

2. In a tube, the plate receives the electrons emitted by the cathode. In a transistor, it is the collector which receives the electrons or holes originating in the emitter. Thus plate and collector perform similar functions.

3. In a tube, plate current is controlled by control-grid-to-cathode bias. Similarly, in a transistor, collector current is controlled by base-to-emitter bias. In a tube, the input signal is most frequently applied between the control grid and the cathode. In a transistor, the input

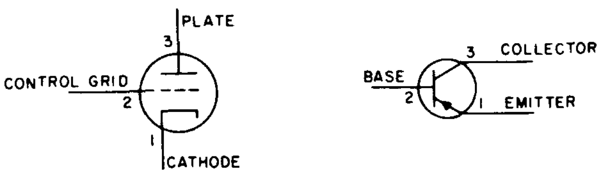

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Figure 13-4.—Comparison of transistor and vacuum tube elements.

signal is most frequently applied between the base and the emitter. It thus is apparent that the base of a transistor is comparable to the control grid of an electron tube.

Like electron tubes, transistors come in various shapes and sizes and often are classed in special categories according to their use and application. The characteristics of each of these devices are usually presented in SPECIFICATION SHEETS or they may be included in tube or transistor manuals.

It should be noted that the primary difference between the operation of a transistor and an electron tube is that the electron tube is a voltage-operated device and the transistor is a current-operated device.

The comparison of a given transistor and electron tube shows that there is great similarity between the functions of a transistor and those of an electron tube. Therefore, any knowledge picked up by the technician in his work on electron tube equipment will be useful in the servicing of transistorized circuits. However, there are great differences between a transistor and an electron tube from the stand point of servicing. For instance, the reliance placed on the senses of sight, touch, and smell in the visual inspection of electron tube circuits is not feasible in the case of transistor circuits. Many transistors develop so very little heat that nothing can be learned by feeling them. High-frequency transistors hardly get warm. Usually, if a transistor is hot enough to be noticeable, it has been damaged beyond use (except special or high-power transistors).

In the case of an electron tube, which is usually of the plug-in type, a quick test is sometimes made by the PART SUBSTITUTION method; that is, by replacing the tube suspected of being faulty with one known to be good. In transistorized circuits, the transistors are frequently soldered and part substitution becomes impractical. Furthermore, indiscriminate substitution of semiconductors should be avoided; it is preferable to test transistors IN-CIRCUIT.

The technician will find more transistors than tubes in two similar equipments, which means more stages to check out. This is true because of the lower gain and power capacity of the transistor. However, the first step in troubleshooting transistor circuitry, as in the troubleshooting of electron tube circuitry, is a visual inspection of the entire equipment. Loose connections, broken leads, and any other visible damage should be repaired before undertaking the next step of the troubleshooting procedure. A careful visual inspection will frequently shorten what could otherwise be a lengthy service job.

When the visible defects have been corrected, experience has shown that it is more efficient first to determine the defective stage by means of a signal-substitution or signal-tracing method and then to analyze carefully that stage for defective components. To apply the troubleshooting method recommended, a voltmeter, ohmmeter, and a signal generator are required.

The general rule (logical troubleshooting method; steps 3, 4, 5, and 6) to be followed in servicing electron tube or transistor equipment is: first, use the signal generator to locate the defective stage or interstage components, then apply the voltmeter and ohmmeter to determine the defective part or parts.

Most good-quality test equipment used for electron tube circuit troubleshooting may also be used for transistor circuit troubleshooting. However, before employing any test equipment, make sure that it meets the requirements given in the paragraph below.

Signal generators, both R-F and AUDIO, may be used if the power supply in these equipments is isolated from the power line by a transformer. Before any tests are made with a signal generator, a common ground wire should be connected from the chassis of the equipment to be tested to the chassis of the signal generator before any other connections are made.

Signal tracers may be used with transistor circuits if the precautions concerning the power supplies in signal generators are observed. Many signal tracers use transformerless power supplies; therefore, to prevent damage to the transistor, an isolation transformer must be used.

Multimeters that are used for voltage measurements in electron tube equipment or transistor circuits should have a high ohms-per-volt sensitivity to provide an accurate reading. A 20,000 ohm-per-volt meter or an electronic voltmeter with an input resistance of 11 megohms or higher on all voltage ranges is preferred on transistor circuits.

Ohmmeter circuits which pass a current of more than 1 ma through the circuit under test cannot be used safely in testing transistor circuits. Therefore, before using any ohmmeter on a transistor circuit, check the current it

passes on all ranges. DO NOT use any range that passes more than 1 ma.

Conventional test prods, when used in the closely confined areas of a transistor circuit, often are the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage but in transistor circuits this momentary short can ruin a transistor. Also, since transistors are very sensitive to improper bias voltages, the practice of trouble-shooting by shorting various points to ground and listening for a CLICK must be avoided. In electron tube circuits, momentary shorts may occasionally cause a component to burn out, although they rarely affect tubes. In a transistor circuit, the transistor is usually the weakest link, and it becomes the victim.

The sensitivity of a transistor to surge currents should always be borne in mind whenever making any voltage measurements in transistor circuits.

Another change from conventional trouble-shooting procedure that is required by transistors is the use of a small, low-wattage soldering iron (or pencil) possessing a narrow point or wedge. Wattage ratings on the order of 35 to 40 watts are satisfactory. The common type of soldering gun or iron used on electron tube circuits should never be used on transistor circuits.

Always remember that because these units are small and have many features and characteristics which differ from those of the more familiar electron tubes, the servicing of transistor equipment requires a modification of presently used and familiar techniques. REMEMBER, TRANSISTORS ARE CURRENT-OPERATED DEVICES: ELECTRON TUBES ARE VOLTAGE-OPERATED DEVICES.

Transistor Specifications

Semiconductors, like electron tubes, are available in a large variety of types, each with its own unique characteristics. The characteristics of each of these devices are usually presented in SPEC SHEETS, or included in tube or transistor manuals. The specifications usually cover the following items:

1. The lead paragraph of a semiconductor specification sheet is a general description of the device, and contains three specific pieces of information:

   a. The kind of semiconductor. This covers the semiconductive material used, such as germanium or silicon; whether type PNP or NPN, etc., and the type of construction, whether alloy-junction, grown or diffused junction, etc.

   b. Some of the major applications are listed, such as audio amplification, oscillator, and high-gain R-F amplification.

   c. General sales features, such as size and packaging.

2. The ABSOLUTE MAXIMUM RATINGS of voltages and collector current. These ratings should not be exceeded under any circumstances, as semiconductor failure may result.

3. Collector power dissipation. The power dissipation of a transistor is a function of its junction temperature and the ambient temperature. The higher the temperature of the air surrounding the transistor, the less power the device can dissipate. A factor telling how much the transistor must be derated for each degree of increase in the ambient temperature is usually given.

4. Current transfer ratio. This is another name for alpha or beta (discussed in detail later).

5. Collector cutoff current. This is leakage current from collector to base when no emitter current is being applied.

Additional information is provided for engineering design purposes.

Diode and Transistor (Designation System)

A standardized system of numbers and letters is used for designating diodes and transistors:

1. The first number indicates the number of junctions. Thus 1 designates a diode; 2 designates a transistor (which may be considered as made up of two diodes, the base-emitter and base-collector diodes); 3 designates a tetrode, a four-element transistor.

2. The letter N following the first number indicates a semiconductor.

3. The 2 or 3 digit number following the letter N has no particular significance, except that it indicates the order or registration. When this number is followed by a letter, it indicates a later, improved version.

Thus, a semiconductor designated as type 2N345 signifies that it is a three-element transistor of semiconductor material and that it is an improved version of type 345.

Transistor Lead Identification

The arrangement and coding of transistor leads is shown in figure 13-5. Part A shows a

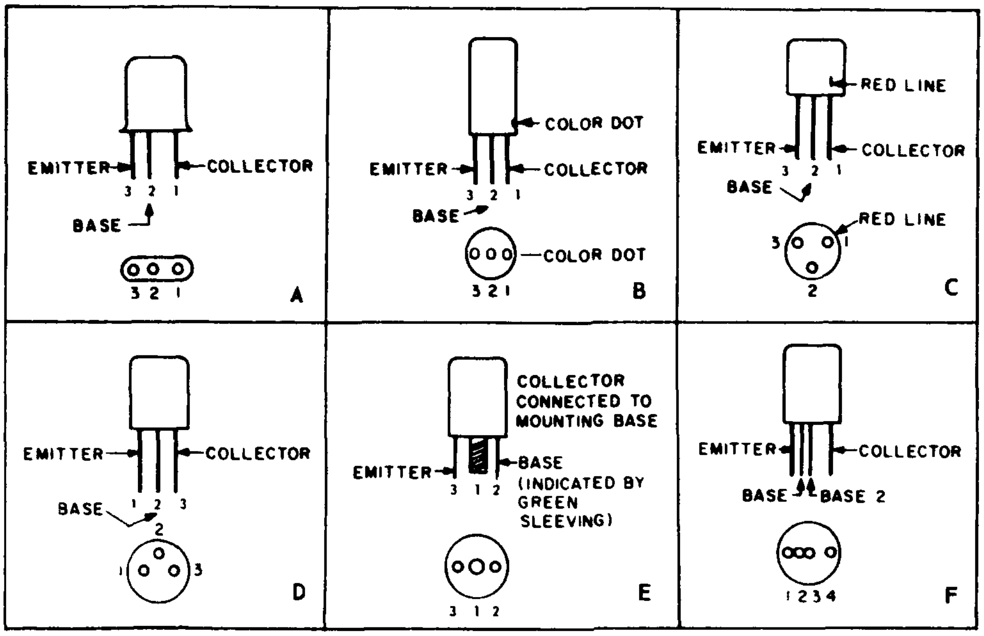

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Figure 13-5.—Transistor lead identification.

transistor in an oval case. The collector lead is identified by a wide space between it and the base lead, which, in turn, is followed by the emitter lead. Part B shows a round case with three leads in line and equally spaced. The collector lead is marked on the case by means of a color dot, usually red. The other two leads are the base and emitter, in that order. In part C, the collector lead is marked by a red line on the case. The base and emitter leads follow clockwise around the circle, in that order. In part D the leads are located at three points of a quadrant. When viewed from the bottom in a clockwise direction, the first lead following the blank space is the emitter, followed by the base and collector. Part E shows a conventional power transistor where the collector is connected to the mounting base, the mounting bolt forming the conductor for the collector. The base lead is identified by its green sleeving.

It should be noted that sometimes, even where all three leads are present, one of the elements may be connected to the mounting base to provide additional cooling.

Part F shows a tetrode. The collector is identified by the wide space between it and the other leads, which are: base 2, base, and emitter, in that order.

Transistor Heat Dissipators

As the complexity of transistorized electronic equipment has increased, the space available for individual components has almost disappeared. This trend in design has meant more heat generated with less space in which it can be dissipated, causing an ever-increasing environmental temperature in which the transistor must operate. The reliability of a transistor, like that of an electron tube, is dependent on its ability safely to absorb and dissipate the internally generated heat while operating at the increased temperature resulting from its own heat. For this reason, transistor heat dissipating devices are finding widespread application to prevent the effects of higher operating temperature and to increase the power dissipating ability of the transistor. These devices utilize the natural methods of conduction, convection, and radiation to reduce case and junction temperatures and to increase overall reliability.

Transistor retainer and heat dissipators (figure 13-6) are relatively simple in their design and construction and require little or no maintenance other than to ensure that the mounting hardware used to attach the heat dissipator to the chassis or metal bracket is

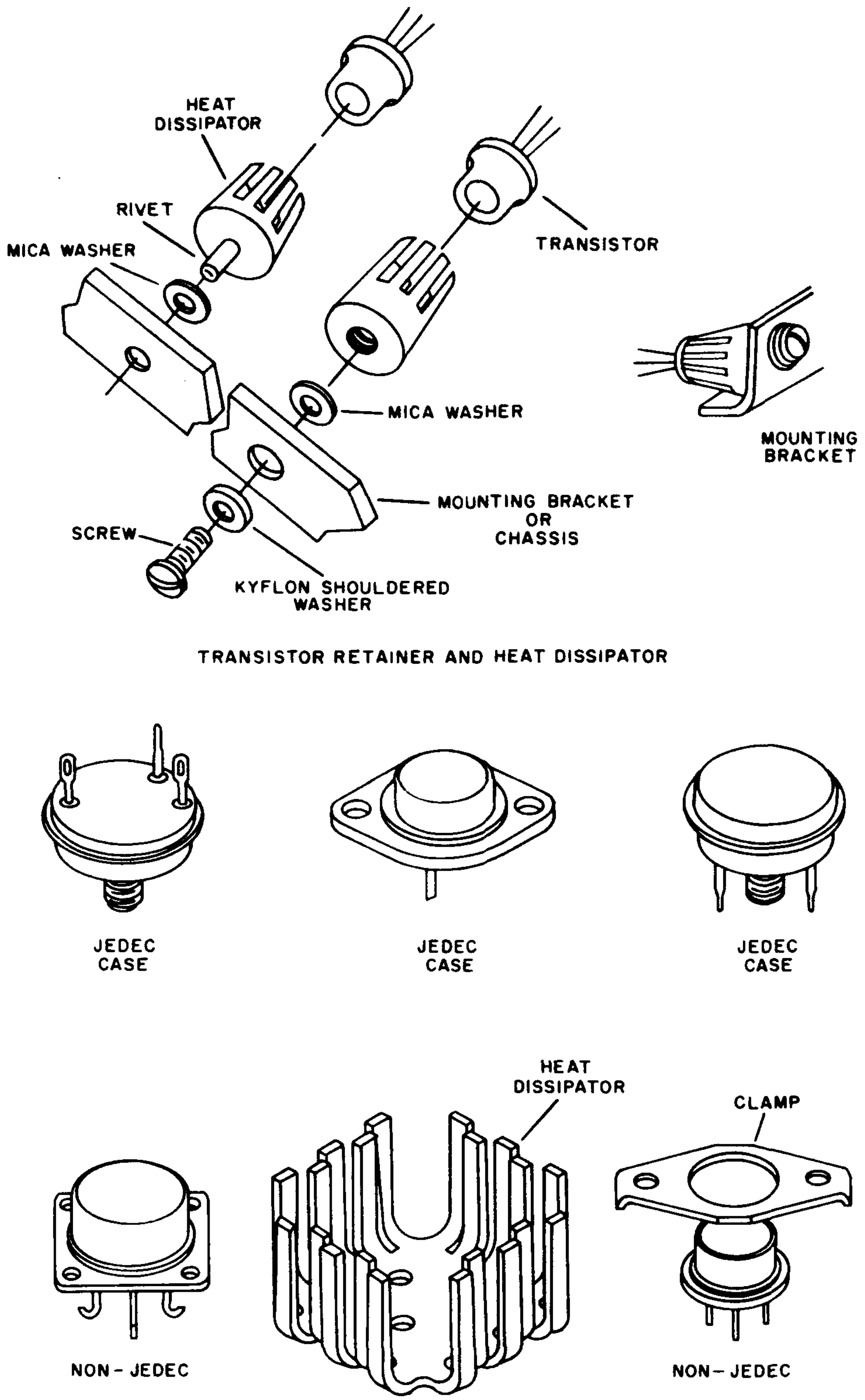

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Figure 13-6.—Transistor heat dissipators.

secure and in place. In some cases, the removal of the heat dissipator may be required to reach inaccessible locations in equipment. In removing the dissipator, be careful not to damage the fragile, brittle leads of the transistor. When the dissipator is disassembled, all mating surfaces should be inspected to ensure that they are free from burrs or sharp edges. Any existing burr or sharp edge must be removed, otherwise, the thin mica washer or mica material used to insulate electrically the transistor from the chassis or metal surface areas may be punctured, impairing its dielectric properties and forming a path for current leakage.

NOTE: A thin coat of silicone grease or similar compound applied to the surface areas of the mica insulating material will improve its dielectric properties.

Servicing Precautions

Since the transistor is probably one of the most reliable components, it should be the last to be suspected. Again, this is contrary to the long-established practice used in electron tube equipments, where the tubes normally are checked first. Because of their reliability, transistors are generally soldered in the circuit, particularly in printed circuits. Removing and testing each transistor will not only unnecessarily subject the transistor to heating, but may also result in damage to some other component, particularly in the case of a printed circuit board.

However, if the transistor itself is suspected it can be removed from the equipment for testing. In sets employing sockets for the transistors, it is only necessary to remove the transistor from the socket. If the transistor is soldered and it becomes necessary to unsolder it, extreme care must be taken to prevent damage to the transistor by the heat from the soldering iron. Also, the leads must be handled carefully as they are very brittle.

CAUTION: Never remove or replace a transistor while the battery or power source is connected to the set. Failure to observe this caution may result in damage to the transistor from surge currents, etc.

Although generally more rugged than the electron tube, the transistor is affected by electric shock, heat and humidity.

One of the most frequent causes of damage to semiconductor units is the electrostatic discharge from the human body when the unit is handled. Such damage may be avoided by discharging the body to the equipment before handling the unit.

A semiconductor unit may also be damaged by r-f fields. It is therefore essential that the unit be protected by a metal container until ready for use, at which time the equipment should be deenergized before the semiconductor is inserted.

When it becomes necessary to replace a transistor where the leads have been soldered, the following precautions should be taken. Before removing the old transistor, note the orientation of the collector, base, and emitter leads. Cut the leads of the new transistor to the proper length, using sharp cutters to prevent undue stress on the leads entering the transistor. Then, with the transistor properly positioned, solder the leads to the connections, using the proper solder, soldering iron, and a heat sink.

For stability of the electrical characteristics, the maintenance of the tranistor hermetic seals cannot be over emphasized. They not only maintain the carefully controlled environment in which the transistor is sealed, they also exclude moisture which causes instability. (While a transistor is warming up after exposure to low temperature, moisture may collect on the transistor surfaces, causing a large temporary increase in the collector current.)

The minute power requirements of transistor circuits make it economically feasible to operate transistorized equipment with batteries, even where the equipment is subject to continuous use. By using careful construction techniques, the transistors of today are capable of operation in excess of 30,000 hours at maximum rating without appreciable degradation. Either conventional zinc-carbon batteries or the newer mercury batteries may be used. BATTERY ELIMINATORS SHOULD NEVER BE USED AS THE SOURCE OF POWER FOR TRANSISTORS OR ANY OTHER SEMICONDUCTOR DEVICE. Because of the low current drain of transistor circuits, the voltage regulation of battery eliminators is poor.

In handling transistors, it should be remembered that temperature is the most important factor affecting transistor life, and that it is important to keep both the transistor and the ambient temperature as low as possible. It has been estimated that for every 10°C the junction temperature is lowered, the life of the transistor is doubled.

Printed Circuits

Although the troubleshooting procedure for printed circuits are similar to those for conventional circuits, the repair of printed circuits requires considerably more skill and patience. The printed circuits are small and compact; thus personnel should become familiar with the special servicing techniques required.

In all instances, it is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been performed. Not all personnel having access to this type of equipment have the skill and dexterity required; hence some preliminary service may be necessary. By observing this precaution you may save a great deal of time and labor.

The defective part should be pinpointed by a study of the symptoms and by careful and patient analysis of the circuit (using the logical six-step method) before attempting to trace trouble on a printed circuit board. Ascertain whether the conducting strips are coated with a protective lacquer, epoxy resin, or similar substance. If so, carefully scrape it away, or, better still, use a needle or chuck type needle probe, as shown in figure 13-7, which will easily penetrate the coating for continuity check.

Breaks in the conducting strip (foil) can cause permanent or intermittent trouble. In many instances, these breaks will be so small that they cannot be detected by the naked eye. These almost invisible cracks (breaks) can be located only with the aid of a powerful hand- or stand-held magnifying glass, as illustrated in figure 13-8.

The most common cause of an intermittent condition is poorly soldered connections. Other causes are: Broken boards, broken conducting strips, fused conducting strips, arc-over, loose terminals, etc.

To check out and locate trouble in the conducting strips of a printed circuit board, set up a multimeter (one which DOES NOT pass a current in excess of 1 ma) for making point-to-point resistance tests, as shown in figure 13-9, using needle point probes. Insert one point into the conducting strip, close to the end or terminal, and place the other probe on the terminal or opposite end of the conducting strip. The multimeter should indicate continuity. If the multimeter indicates an open circuit, drag the probe along the strip (or if the conducting strip is coated, puncture the coating at intervals) until the multimeter indicates continuity. Mark this area and then use a magnifying glass to locate the fault in the conductor (figure 13-8).

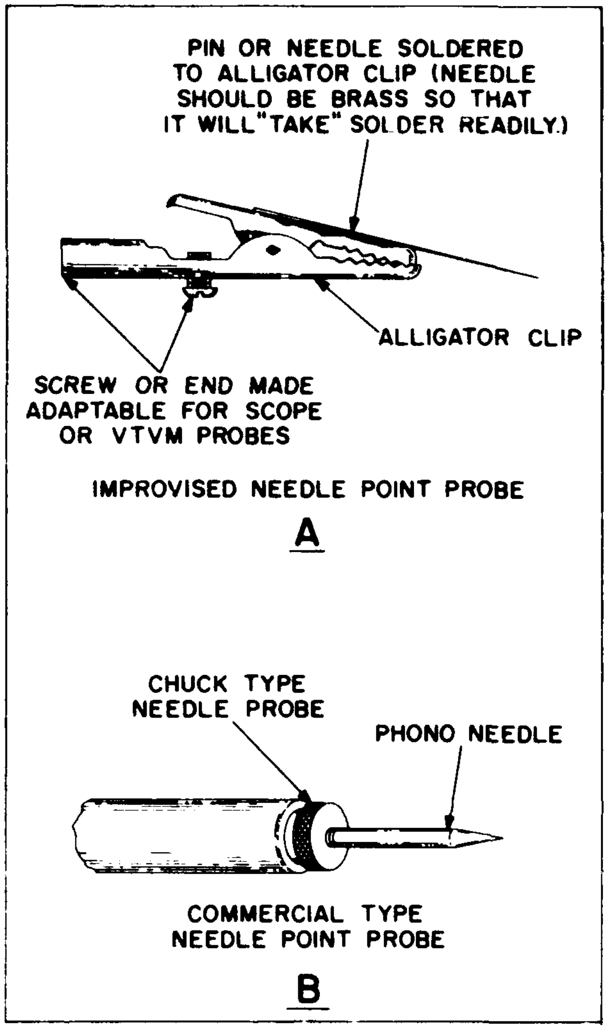

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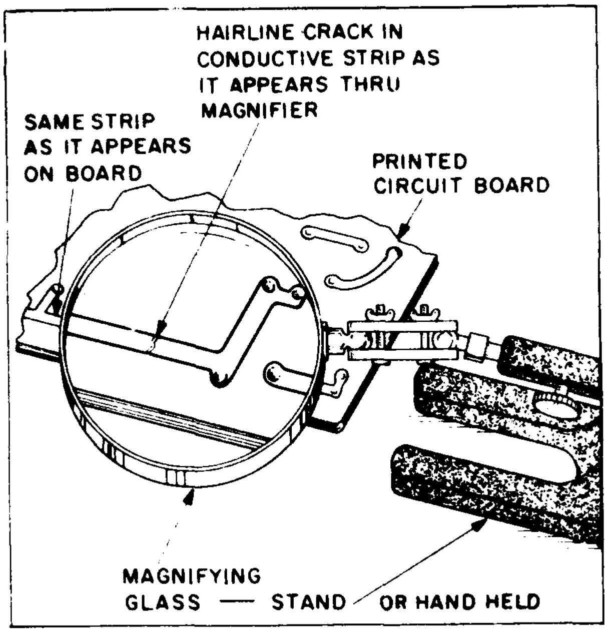
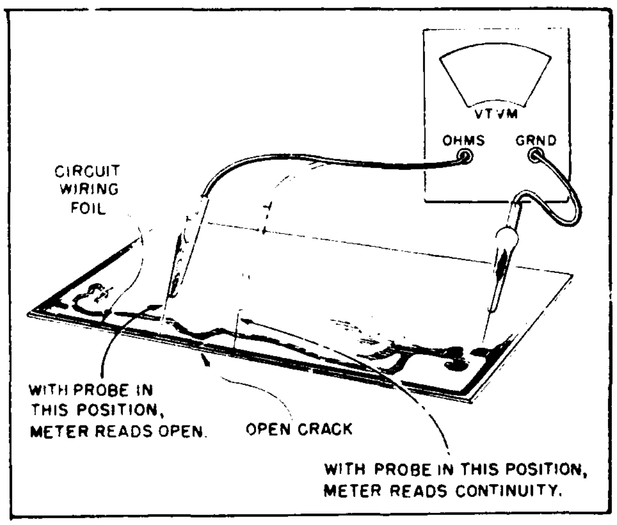
Figure 13-7.—Needle probes.

CAUTION: Before using an ohmmeter for testing a circuit containing transistors or other voltage-sensitive semiconductors, check the current it passes under test on all ranges. DO NOT use a range that passes more than 1 ma.

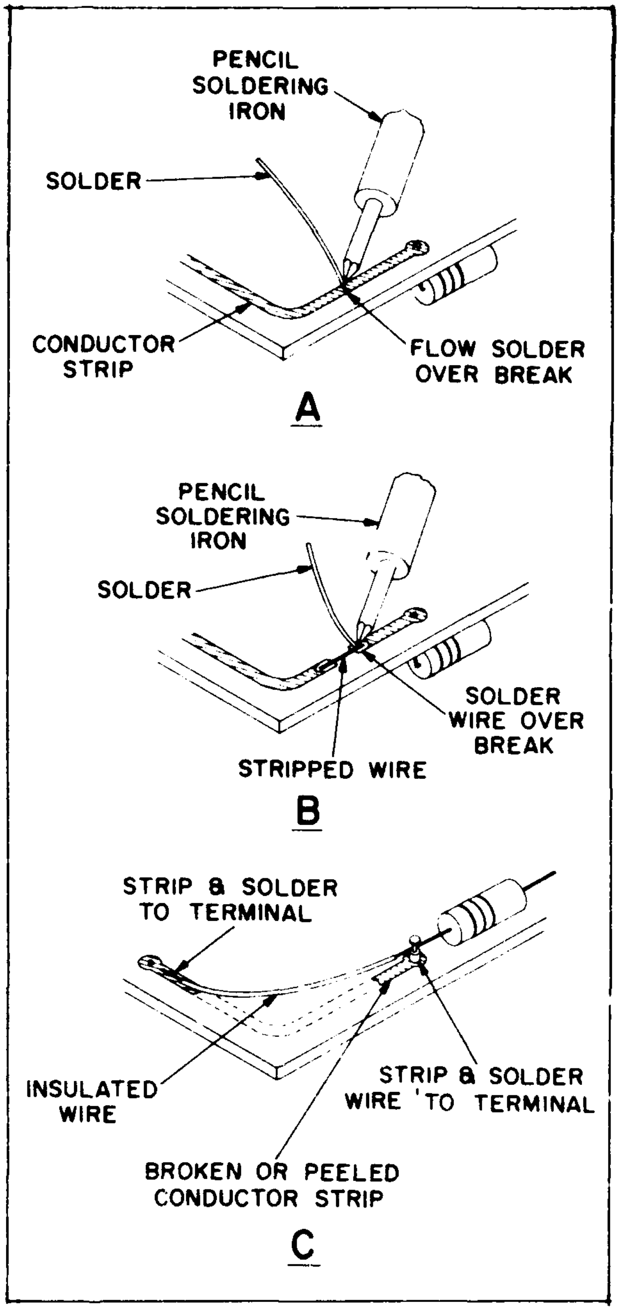
If the break in the conducting strip is small, lightly scrape away any coating covering the area of the conducting strip to be repaired. Clean the area with a firm-bristle brush and approved solvent (see Handbook of Cleaning



70.110
Figure 13-8.—Using a magnifyin glass to locate a hairline crack.



70.111
Figure 13-9.—Using a VTVM to locate a break in a conductive strip.



70.112
Figure 13-10.—Three methods of repairing broken conducting strips.

Practices, NavShips 250-342-1), then repair the cracked or broken area of the conducting strip by flowing solder over the break (fig. 13-10A). If there is any indication that the strip might peel, bridge the break with a small section of bare wire (approximately 2 inches) by the method shown in figure 13-10B. Apply solder along the entire length of the wire

to bond it solidly to the conducting strip. Considerable care must be exercised in applying the solder to prevent it from flowing onto or near an adjacent strip. Keep the solder within the limits of the strip that is being repaired.

If a strip is burned out, or fused, cut and remove the damaged strip. Connect a length of insulated wire across the breach or from solder-point to solder-point (fig. 13-10C).

It is best not to glue or bond a conducting strip that has been lifted or peeled from the board at a terminal or solder point. Instead, clip off the raised section and replace it with insulated hookup wire from solder-point to solder-point.

Printed circuit boards are frequently subject to leakage and shorts, especially if the spacing between conductors is very close, or by the careless formation of a solder bridge between the conducting strips during soldering. NOTE: After repairs, always scrutinize the board for solder droppings that may cause possible shorts.

Frequently, a low-resistance leakage path will be created by moisture and/or dirt that has carbonized onto the phenolic board. This leakage can be detected by measuring the suspected circuit with a multimeter. To overcome this condition, thoroughly clean the carbonized area with solvent (methyl Chloroform GM 6810-664-0387) and a stiff brush. If this does not remove it, use a scraping tool (spade end of a solder-aid tool or its equivalent) to remove the carbon, or drill a hole through the leakage path to break the continuity of the leakage. When the drilling method is used, be careful not to drill into a part mounted on the other side.

Occasionally, a conductor will rupture or fuse, usually because of a current overload. Generally, the rupture, or fusing, is the result of limited spacing and narrow conductors. Do not try to repair this type of damage, other than to bridge the rupture, or fused area, with a length of insulated wire (fig. 13-10C).

Most printed circuit boards have areas of conduction, known as GROUNDING CONDUCTORS, at each edge of the board or on the parts-mounted side of the board. These grounding conductors are conducting strips, used for grounding parts and as a mounting contact for the chassis or common ground. Sometimes an intermittent condition will result if the grounding, screws or mounting screws, become loose. If this occurs tighten the screws and then solder a good bond directly from the grounding strip to the chassis or equipment ground. If this is not practical, bond the screws (after tightening) with an epoxy resin or similar compound.

The most common cause of broken boards is droppage. Some boards are broken because of careless handling by service personnel while the equipment is under repair. Be extremely careful at all times while handling a board. Do not flex the board indiscriminately; be especially careful when removing the board or replacing parts; do not force anything associated with the board.

A printed circuit can be flexed to a certain extent; however, flexing may break the board which must then be replaced at a considerable loss of time. To prevent this possibility, it is always good policy to use a chassis-holding jib or vise when servicing printed boards.

Before repairing a broken printed-circuit board, assess the damage. Inspect the condition of the board and the extent of the break. If the board is not too complicated or the damage not too extensive the board can probably be repaired.

After the repairs are completed, clean the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, and then coat the repaired area with an epoxy resin or similar compound. This coating not only will protect the repaired area but will help to strengthen it.

NOTE: When a board is broken, it is much better to replace the entire board. The repair techniques given above are for temporary repair only.

Special Techniques

It is always desirable to replace parts on a printed circuit board without applying heat directly to the conducting strip. This procedure prevents damage to the printed circuit conductors, feed-through devices, eyelets, or terminals, and saves time in repair. It also prevents damage to semiconductors and other heat-sensitive parts that may be in proximity to the part being repaired.

Replacing parts requires that each type of part mounting be considered individually for the best method of removal.

A part to be removed may be too close to a heat-sensitive semiconductor or other part to allow the hot pencil-soldering iron to be applied. A quick test to determine this safe

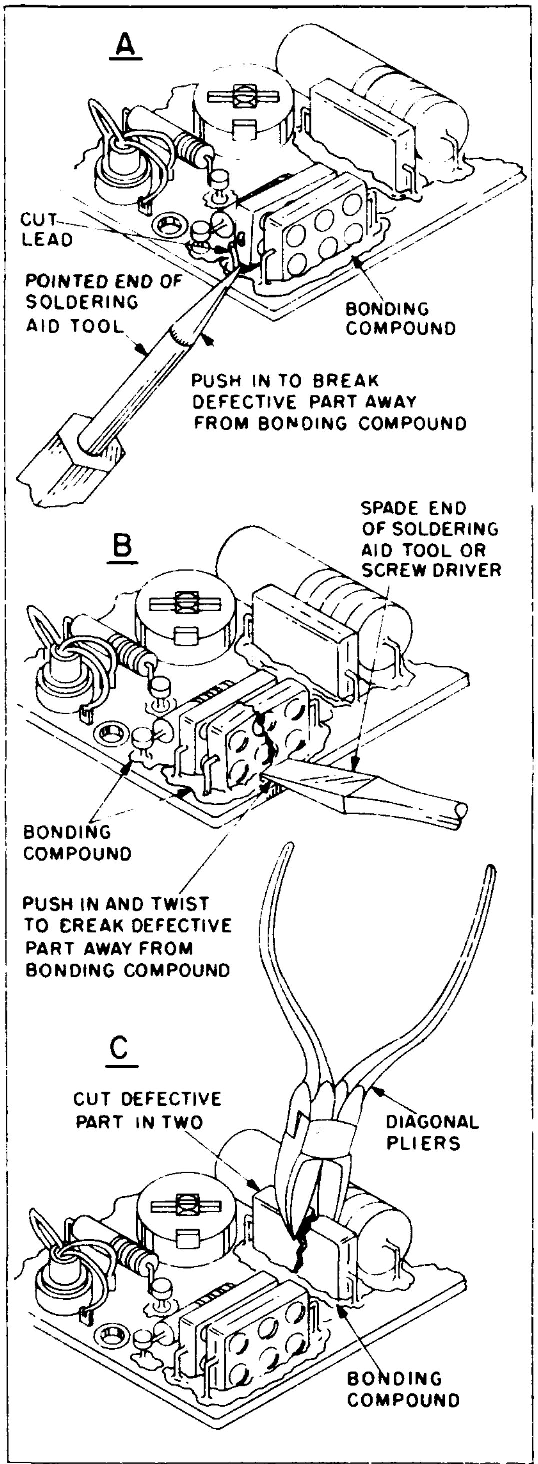
distance is to place your finger between the semiconductor (or heat-sensitive part) and the part to be removed. Place the hot soldering iron in the position to be used. If the heat is too great for your finger it is too hot for the semiconductor. After determining that the heat-sensitive part is too close, place a shield (asbestos or like substance) between the parts before applying the hot soldering iron, and place heat sink clamps on all leads from the heat-sensitive part.

Solid-state parts and their associated circuitry are extremely sensitive to thermal changes. Therefore, particular care must be taken to prevent exposing them to heat. Heat sink and shunts must be applied with shields inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron. Solid-state parts and associated assemblies require the same care in handling and skill of repairing that is applied to assemblies in equipment of unitized or modular construction containing transistors, tantalum capacitors, crystals, etc.

Removal of an axial-lead part that has been bonded to a printed circuit board (with an epoxy resin or similar compound) can be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to be used depends upon the part itself and its location.

If the defective axial-lead part cannot be removed by heat, cut or break the part away from the bonding compound. Figure 13-11 illustrates two different methods of breaking the part away from the bonding compound where the part is too close to other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool. Wherever possible, cutting the defective part with end-cutting pliers or diagonals, as shown in part C, is the preferred method to use.

Regardless of which tool is employed (round-pointed or spade type), great care must be used in its application to prevent the printed circuit board or other parts from being damaged or broken. Apply the point of the tool against the bonding compound, between the part and the printed circuit board. Use the tool in such a manner that it works away the bonding compound from the part to be broken away until enough has been removed for the tool to exert



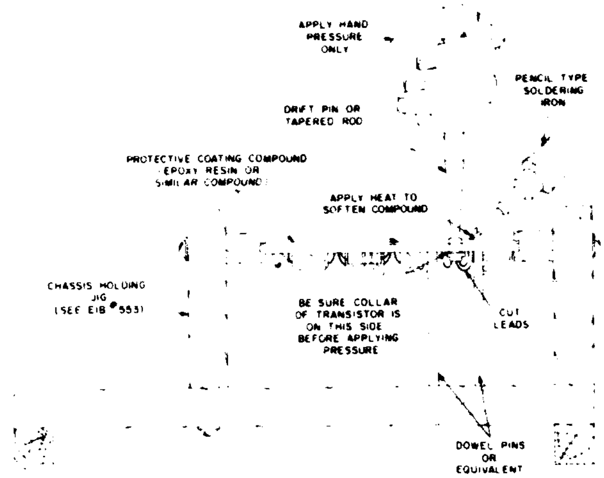
70.113
Figure 13-11.—Removing a defective part from bonding compound.

pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board.

CAUTION: NEVER APPLY MUCH PRESSURE AGAINST A PRINTED CIRCUIT BOARD.

After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board. Clean the area thoroughly before installing the new part. Do not remove the compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as the new part; thus, inserting the new part in this mold helps to secure it from vibration. After the repairs have been completed and the circuit tested, spray the newly soldered area with an insulating varnish or equivalent. Coat the new part or parts with a bonding compound (ECCO-BOND-"55" by Emerson and Cuming, Inc,; relix-R-313 by Carl H. Briggs Co.) or equivalent.

To replace a proven defective transistor, first cut all of its leads, and then remove it from the assembly. Transistors are mounted on circuit boards in many different ways; thus it is necessary to study how a particular transistor is secured before attempting to remove it. A transistor with clamp-type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire or spring clamp around it. Remove this clamp before pulling the transistor out of the socket. In some instances the transistor is bolted through the board. Remove the nut and washer, and then remove the transistor. Where vibration is a prime factor, the manufacture mounts the transistor through the circuit board and bonds it (with epoxy resin or similar compound). For this type, a flat-ended round-rod type tool (drift punch) of a diameter less than that of the transistor case is required. Be sure that the printed circuit board on which the transistor is mounted is secured in a proper device, and in such a way that pressure exerted against the board will be relieved by a proper support on the other side (fig. 13-12). Apply a hot-pencil soldering iron to the bonding compound and simultaneously apply the drift punch against the top of the transistor, exerting enough pressure to remove the transistor from the softened compound, and then on through and out the board (fig. 13-12).



70.114

Figure 13-12.—Removing a transistor that has been through-board mounted.

Before installing the new transistor, great care must be taken to prepare the part for installation.

Test the transistor in a transistor tester (TS-1100/U or equivalent) before installing. This precaution will assure that the transistor is good before it is installed. For several reasons transistors can and do become defective in storage. Therefore, always check them before installation.

Pre-shape and cut the new transistor leads to the shape and length required for easy replacement. Use sharp cutters, and do not place undue stress on any lead entering the transistor. The leads are fragile, and are therefore susceptible to excessive bending or too sharp a bend. Shape any bend required in a gradual curve, and at least 1/4 inch to 3/8 inch from the base of the transistor. A safety measure which can be taken to ensure that the lead will not break off at the base is to use two pairs of needle-nose pliers. With one pair grasp the lead close to the transistor base, while shaping the rest of the lead with the other pair.

NOTE: The above procedure and precaution should be applied to any and all semiconductors, tantalum capacitors, and other miniaturized parts in equipment of modular or unitized construction.

After the remianing pieces of the defective transistor-terminal leads have been removed and the terminals on the board cleaned and

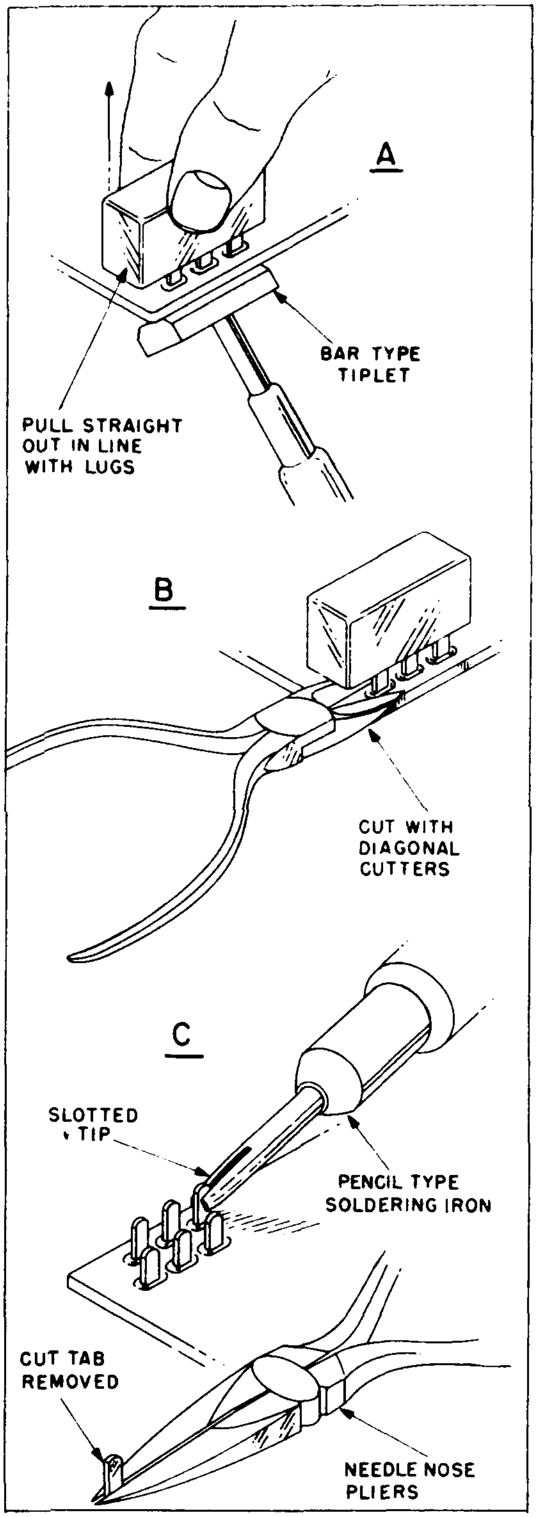
prepared connect the new transistor to its proper terminals.
REMEMBER: Handle any semiconductor or miniaturized part carefully; be gentle and be precise.

When the defective transistor is removed from a through-board mounting, and bonded, care must be taken that the new transistor clears the hole before it is connected to its terminals. If the hole is too large, shim with a thin plastic sleeve (fabricated). If the hole is too small, ream it to accept the new transistor. Rebond the fitted transistor after TESTING the repaired circuit, and it is proven to be operative. CAUTION: DO NOT USE HEAT TO REBOND REPLACED SEMICONDUCTORS.

To remove and replace a multi-lug part, such as a transformer, choke, filter, or other similar potted, canned, or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove such a part, inspect it carefully to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise, you may break the board by applying undue pressure to it. Never wrench or twist a multilug part to free it, because this will cause the conducting strip to become unbonded from the board. Work this type of part in and out in line with its lugs, while applying a hot-pencil soldering iron (fig. 13-13), using a bar type tiplet adapter or similar desoldering tool.

Whenever possible, cut the conducting or mounting leads and lugs of the defective multi-lug part on the mounting side of the board (fig. 13-13B). Heat and straighten the clipped leads with a hot-pencil soldering iron and slotted soldering-aid tool (or slotted soldering-iron tiplet adapter or similar desoldering tool) applied to the circuit side of the board; pull the leads or tabs through with pliers as shown in part C.

To replace the new multi-lug part, check to be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the multi-lug part. DO NOT FORCE ANY PART INTO POSITION ON A PRINTED CIRCUIT BOARD, BECAUSE THE BOARD MIGHT BREAK OR THE PRINTED CIRCUIT STRIP AND EYELET TERMINAL LIFT. If the part does not position easily, check and rework the terminals and holes (or slots) until it does seat freely; then proceed to solder.



70.115
Figure 13-13.—Removing a defective multi-lug part.

Be very careful when replacing defective parts that have leads terminating on stand-offs, feed-through terminals, etc. In most instances, stand-offs, feed-through terminals, are very small, and mounted on a thin phenolic board; thus they are susceptible to damage by heat and undue pressure.

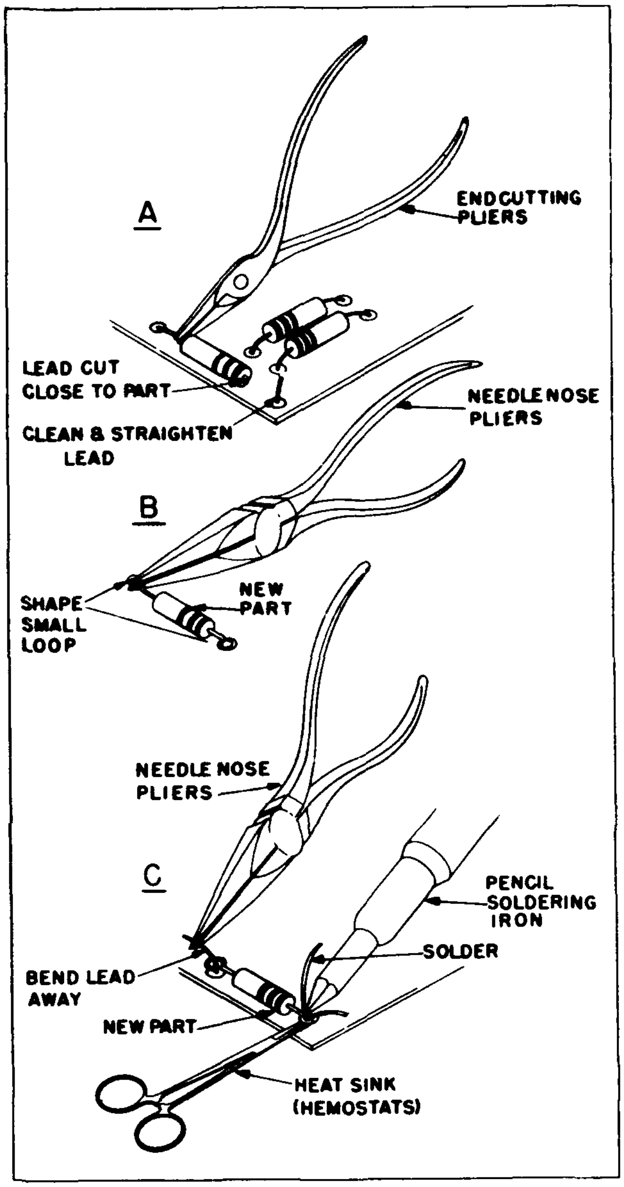
Emergency Techniques

In many instances there is a need for a time-saving technique and procedure for electronic assembly emergency repair. It is desirable, when making an emergency repair, to avoid unnecessary disassembly to expose the defective part when testing and/or repairing. In many instances this can be accomplished by removing only the cover from the assembly.

To remove and replace an axial-lead part (a part mounted by leads that extend from each end, such as a common resistor or capacitor), cut the leads as close as possible to the body of the part, and then connect the leads of the replacement part to the leads remaining on the board. The cutting is accomplished with a pair of end-cutting pliers (fig. 13-14). Clean and straighten the leads remaining on the board. Fashion small loops in the leads of the replacement part (fig. 13-14B) making the loop size and lead length such that the loops slip easily over the leads projecting from the board. Secure these connections by bending the old leads away from the part. Place a heat-sink clamp on the lead from the board,between the board and the connection to be soldered, and then solder the connection (fig. 13-14C). The heat sink prevents the leads connected to the board from becoming unsoldered and causing a short, or open circuit. Always check to be sure that the old leads are properly connected to the conducting strip.

If cutting the leads of a defective axial-lead part would result in leads that are too short for the replacement part to be connected properly, cut the faulty part in half with a pair of diagonal or end-cutting pliers (fig. 13-15A). Then carefully cut away the pieces of the part from each lead (fig. 13-15B). This will yield leads of sufficient length to permit the replacement part to be fitted and soldered as shown in figure 13-14.

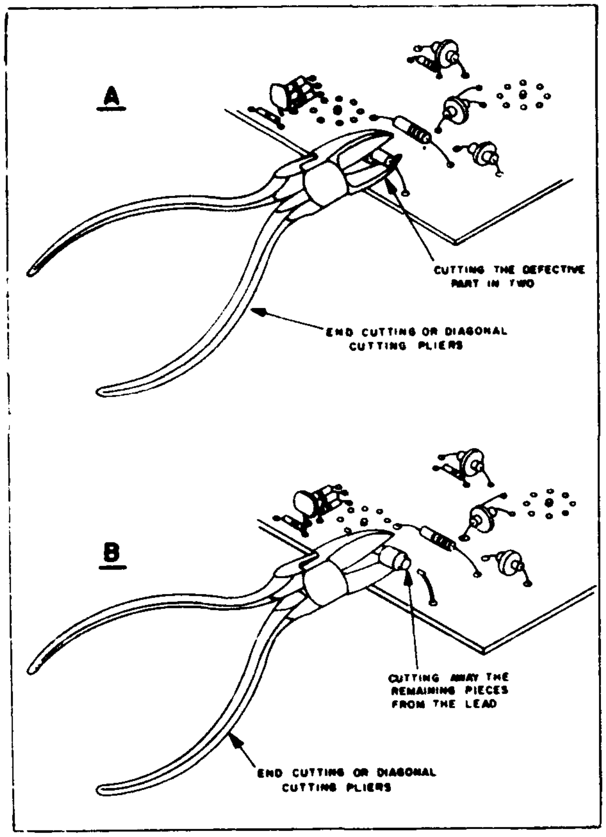
Considerable care must be taken when replacing a defective part that terminates on miniaturized stand-offs, feed-through terminals, etc. These small terminals break easily from applied pressure, or they may melt loose from excessive application of the hot soldering iron. Do not attempt this type of repair on an assembly unless there is no replacement available.



70.116

Figure 13-14.—Replacing a defective part by cutting its leads.

For emergency or temporary repair purposes, the following techniques may be used. Cut the lead close to the defective part (fig. 13-16A). Use a heat-sink clamp (or pliers) next to the

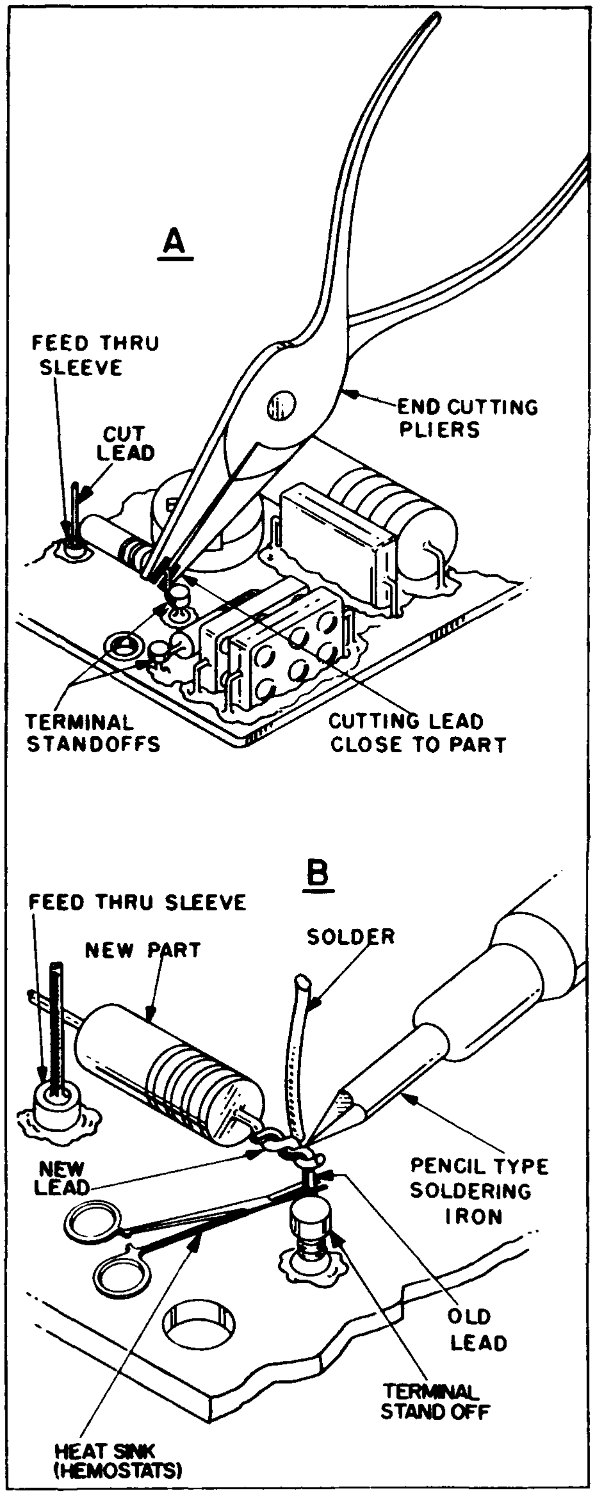


70.117
Figure 13-15.—Cutting the defective part for maximum lead length.

terminal, then solder a spliced lead from the terminal to the new part (fig. 13-16B).

A helpful heat control technique is to place a small piece of beeswax (W9160-253-1172) on the terminal behind the heat sink. When the beeswax melts, the temperature limit has been reached. This is a warning to remove the source of heat immediately. Allow the area to cool thoroughly before attempting to complete the soldering of the connection. Apply a new piece of beeswax to the terminal, repeating this procedure until the connection is satisfactorily soldered.

It is best not to glue or bond a conducting strip on a printed circuit board that has been lifted or peeled from the board at a terminal or solder point. Instead, clip off the raised section and replace it with insulated hookup wire from solder-point to solder-point. However, for temporary or emergency repair, a loose or peeled strip may be bonded back onto the board, using



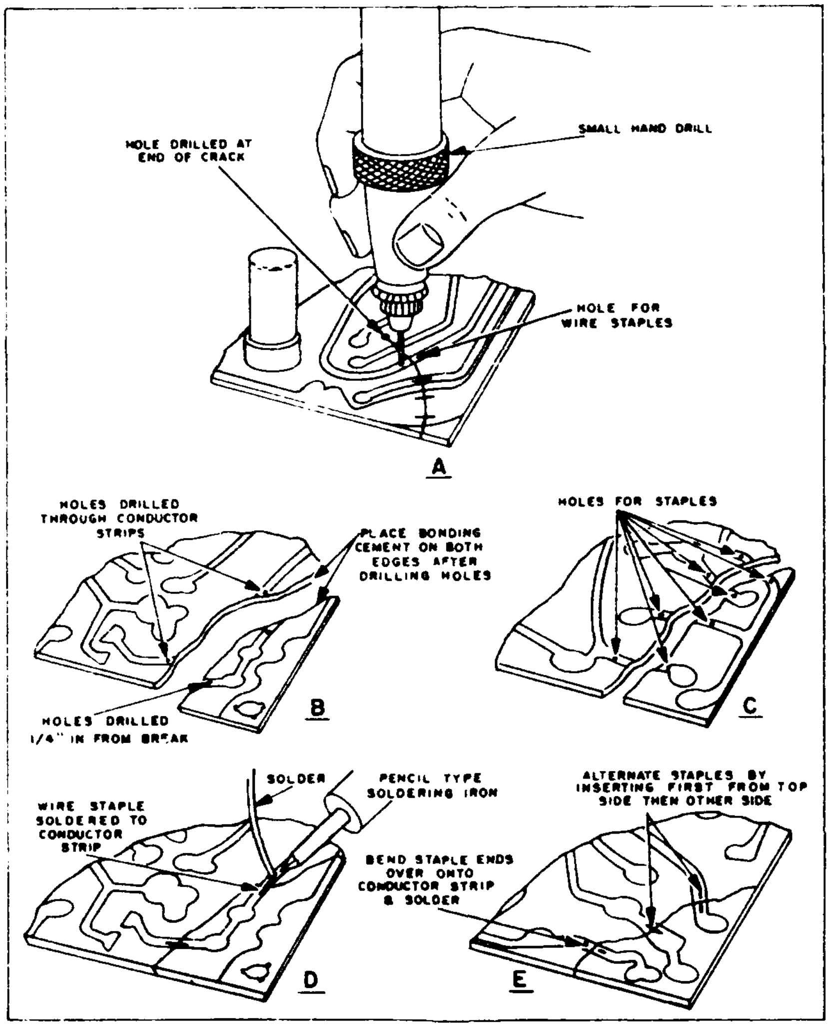
70.118
Figure 13-16.—Removing a defective part from a miniature standoff terminal.

a nonconductive bonding compound ECCOBOND "55" epoxy adhesive, or its equivalent. A silver conductive paint or similar material can also be used to repair printed circuit conductive strips. This technique is satisfactory for temporary or emergency repair, but is not satisfactory for permanent repair.

A broken printed circuit board may have to be repaired in an emergency where no replacement is available. Before repairing the broken board, assess the damage for the extent of the break and the amount of damage to the parts involved. If the board is not too complicated or the damage too extensive, the board can probably be repaired.

If a small portion or corner of the board is broken off, it may be rebonded to the larger section with a nonconductive cement or its equivalent. If cementing is not feasible or does not hold satisfactorily, the pieces can be fastened together with wire staples cut from solid conducting wire of the diameter and length required, depending on the width of the conducting strip to be repaired.

To insert the staples, drill holes about 1/4 inch in from each side of the break (fig. 13-17). The holes should be just large enough to accommodate the wire used for stapling. (This may vary, depending on the width of the conductive strip to be repaired.) Drill the holes through the



70.119

Figure 13-17.—Repairing a broken printed circuit board.

conducting strips so that the staples will provide a good electrical contact across the break; this method will permit the use of enough staples to hold the pieces together without danger to shorts between conductors. If the break is sufficiently large, position additional staples at all points possible to give the board more support.

Where the adhesive and stapling method described above does not provide structural strength or sufficient rigidity, splints or a doubler may be used. Strips of thin card material are glued across the fracture with a nonconductive adhesive. Where needed, additional strength may be obtained by gluing a plate of the card material to the splints with the nonconductive adhesive.

Rebond any loose conducting strips with a non-conductive bonding cement; then apply non-conductive cement to both sides of the break, and join the sections together (fig. 13-17B). Insert half of the measured and precut wire staples from top to bottom, and the other half from bottom to top, bending the ends flush against the board (fig. 13-17E). Solder these staples to the conducting strip (Fig. 13-17D).

If the board is not completely broken but is only cracked, drill a hole at the end of each crack (fig. 13-17A) to prevent further lengthening of the break. Then repair the crack in the same manner as the complete break discussed above.

After the repairs are completed, clean both sides of the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, then coat the repaired area with an epoxy resin or similar compound. This coating not only will protect the repaired area, but will help to strengthen it.

NOTE: The repair techniques given above are for emergency repair ONLY.

Modular Assemblies

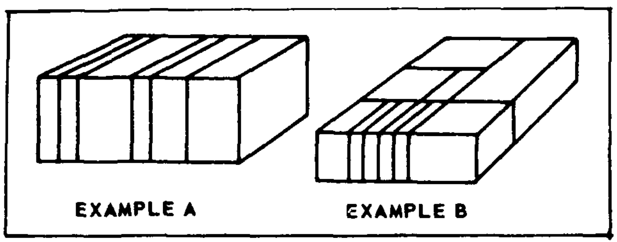
This section provides information so that a technician, using the techniques and procedures discussed in this chapter, can repair and restore modular constructed equipment quickly and efficiently.

The following established definitions will be helpful in understanding the terms involved. A MODULE is defined as A UNIT or STANDARD of measurement—a fixed dimension. A MODULAR ASSEMBLY has outline dimensions which are multiples of a MODULE. An equipment which consists of replaceable assemblies (any type tubes, transistors, etc.), is said to be of unitized construction. MODULAR CONSTRUCTION, then, is a type of unitized construction consisting predominately of MODULAR ASSEMBLIES.

The sketches in figure 13-18 show two possible arrangements of modular construction. Note that the blocks can be arranged in more than one way to approximately the same dimensions.

The original concept of many modular assemblies was that they should not be maintained in the field. The intention was to replace the assembly and ship it back to some repair facility. As assemblies became more complex, the point was soon reached where the extensive supply system required for the replacement concept was too costly. Many equipments built during this initial stage were potted with some secret ingredient to discourage maintenance personnel from tampering with the insides of a black box. When the Navy reassessed this concept, realizing that the fleet must maintain everything it could, most of the equipment manufacturers began to make components accessible. However, many technicians are still convinced that modular assemblies are impossible to repair. This conviction may stem from a lack of experience in working with the printed circuits and the other components in modular assemblies. While it is true that special tools and techniques are required, it is also true that satisfactory repairs can be made to any printed circuit by using just a little care and common sense. Actually, with a little experience, repairs can be made as easily as in conventional assemblies—often more easily because of improved accessibility.

The techniques and procedures previously discussed concerning soldering techniques,



70.120

Figure 13-18.—Two examples of modular construction.

transistors (and heat dissipators), printed circuits (and printed wire, etc.), removing and replacing components and/or parts, and special and emergency techniques, are applicable to all modular constructed MODULAR ASSEMBLIES.

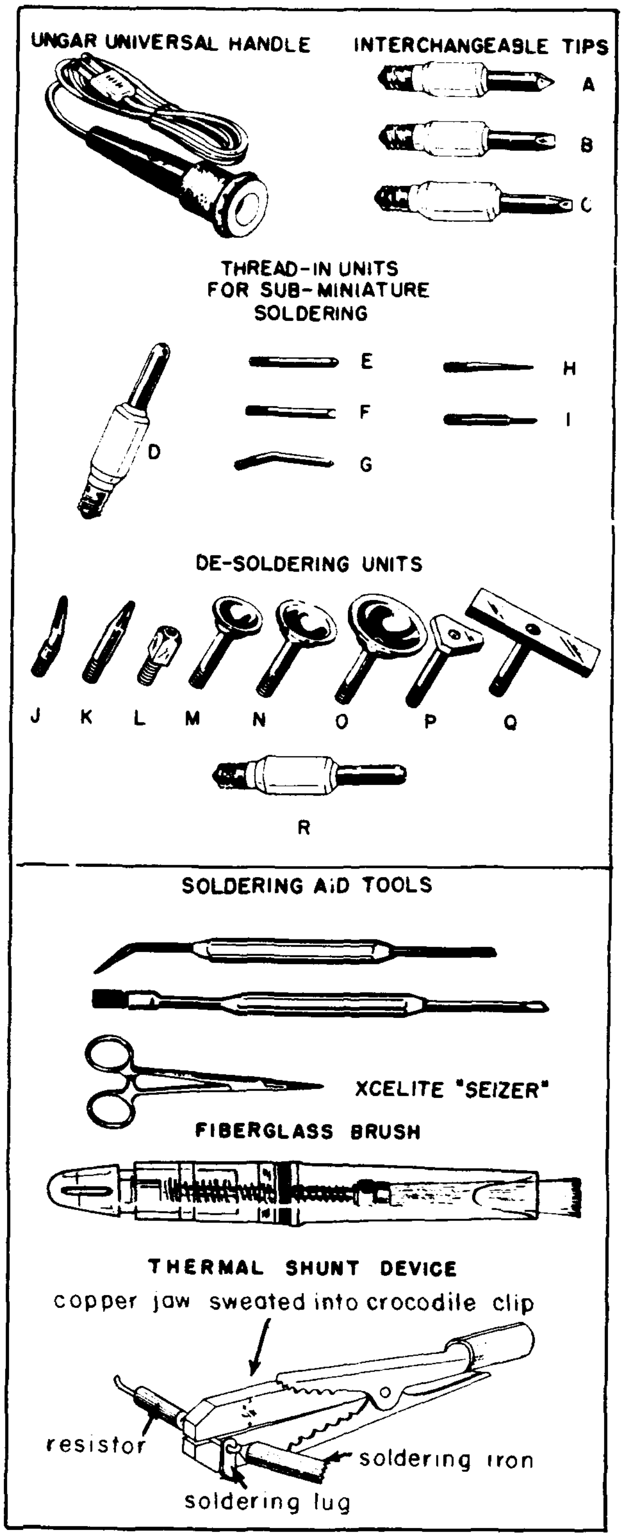
A few examples of techniques and tools needed for the repair and maintenance of modular assemblies are shown in figures 13-19, 13-20, 13-21 and 13-22. Figure 19 shows some of the recommended tools and aids for maintenance; figure 20 shows proper methods of applying and removing solder; figure 21 is an improvised tip for modular repair; and figure 22 gives a few additional soldering iron adapations.

An easy way to reduce the number of hands required for working on printed circuit boards is to construct a chassis holding jig. The one shown in figure 13-23 is versatile enough to accommodate most types of modular assemblies. Along with supporting the board during repair, this jig will prevent slipping or flexing which could result in damage to the board.

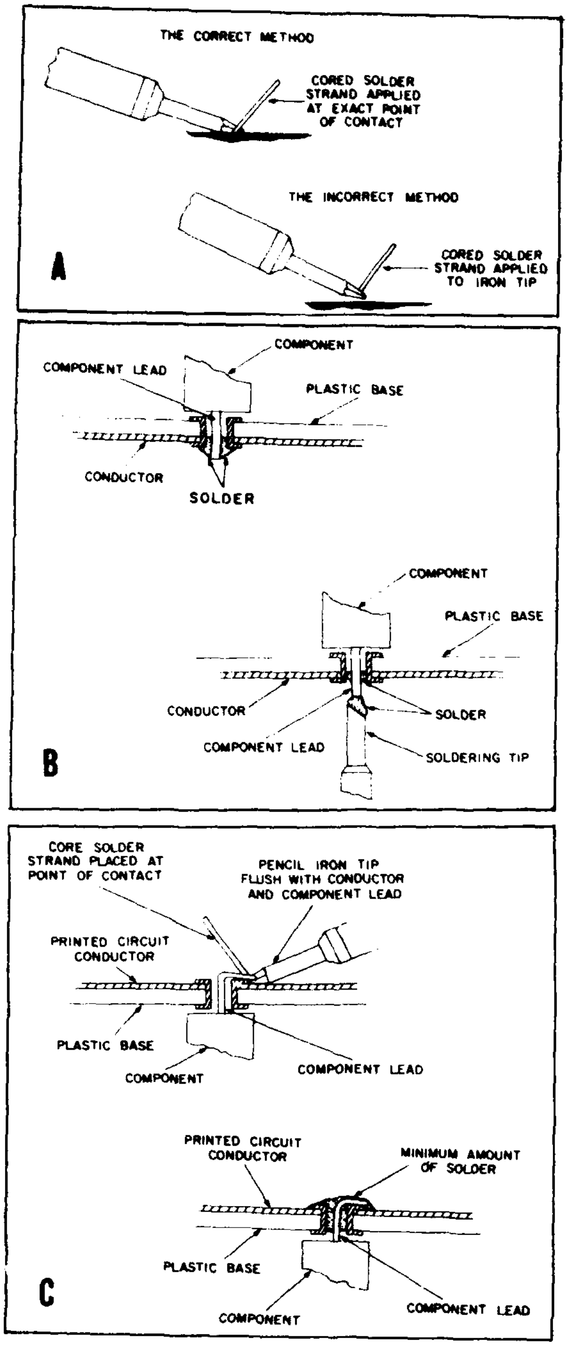
The jig in figure 13-23 is constructed of 1-inch by 4-inch milled lumber of which only 2 feet 3 inches are required if cut to the dimensions given. Three round-head slotted machine screws (10-32, 1 3/4 inches long), three flat washers (0.199 ID, 3/8 inch OD--.064 inch TK), and three common hexagon nuts (No. 10-32) are required. The fixed head and feet are dowel fitted and glued as shown in the illustration. The illustrated jig will hold a modular assembly up to approximately 10 inches wide. The jig should be secured to the work area by utilizing the existing threaded holes on the top of the work bench.

Most of the other tools required for working with modular assemblies are readily available. Items such as diagonal cutters, long-nose pliers, curved needle-nosed pliers, flush-cutting pliers, and tube socket adapters should already be in the shop.

Care in handling and proper packaging, to provide adequate protection against damage in transit or storage, is a must for an electronic assembly or associated repair part. In many cases, misplacement, improper identification or nomenclature, and damage to equipment repair parts in transit and storage are a direct result of thoughtless, careless action in the handling or packaging of the replacement or repairable part by the shipping activity.
REMEMBER: Assembly parts are fragile; careless handling and packaging may damage a

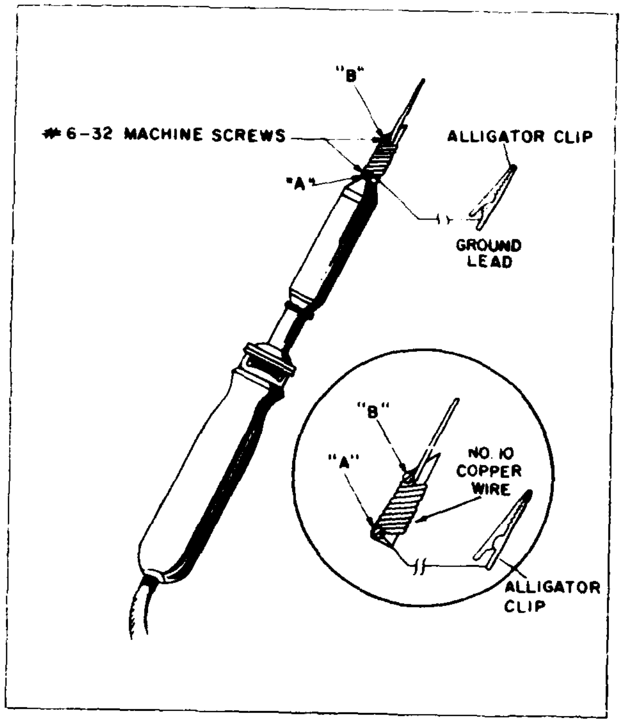


70.121
Figure 13-19.—Recommended tools and aids.



A. The correct and incorrect methods of soldering application.
B. Correct method for removing solder from component without damaging the printed wiring circuits.
C. Correct method for applying solder to a replaced component.

70.123
Figure 13-20.—Soldering techniques.



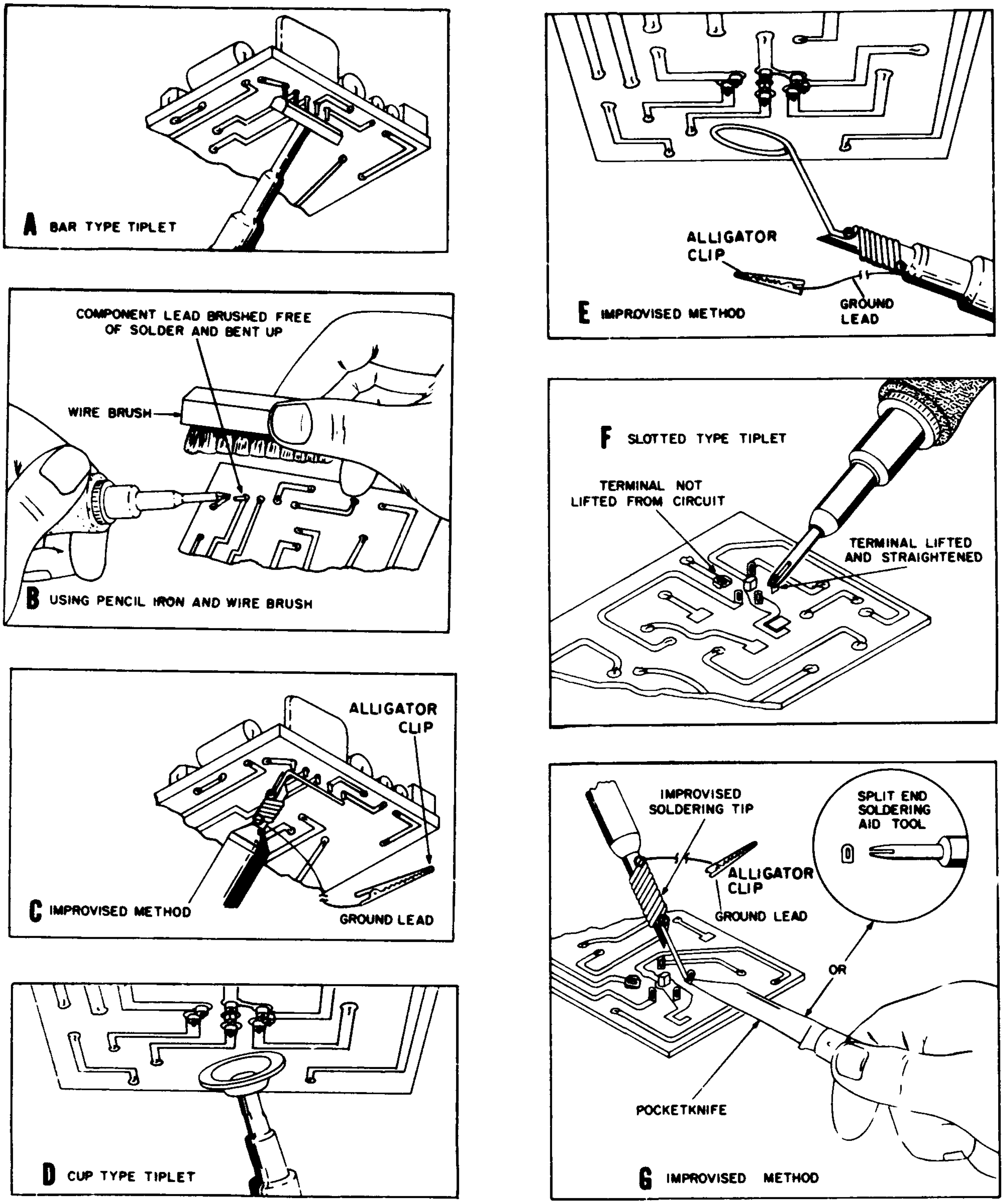
70.123
Figure 13-21.—Improvised soldering tip for modular repair.

replacement or repairable elctronic assembly or associated part beyond use.

Care in handling and protection from damage are just as important for a defective module that can be repaired as for a new module. A new module receives special handling and protection against all normally encountered situations that could either damage or destroy.

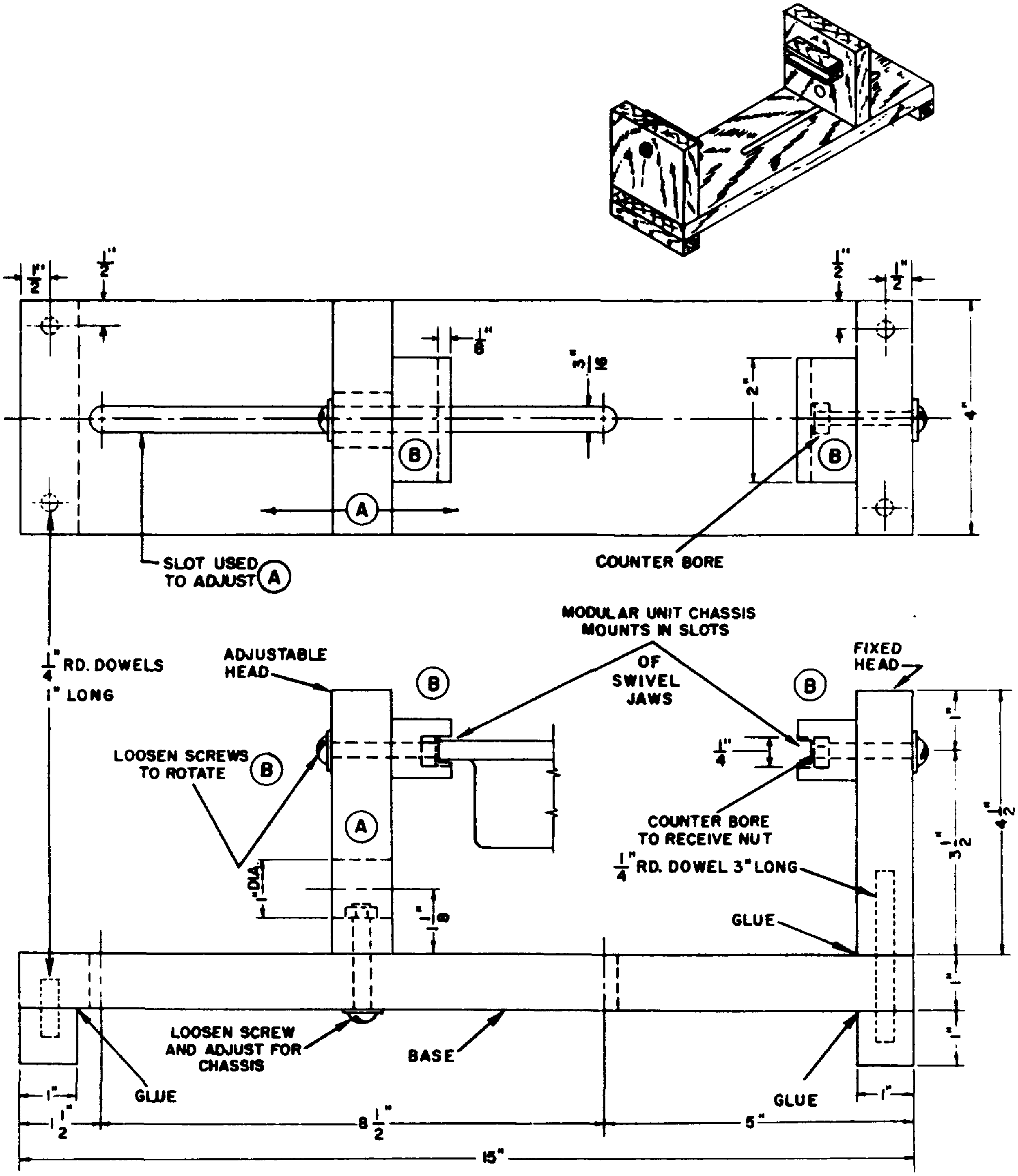
Modular assemblies are shipped in accordance with the applicable packaging specifications. When the issuing activity receives the assembly, the outer casing (crate or carton with the paper packing) is removed and the assembly is stored in a watertight package until drawn by the using activity. Thus the using activity receives with a new module the necessary packaging material to properly protect a defective module.

The correct methods and the proper material to use for protective packaging of defective modular assemblies are shown in figures 13-24,25, and 26. The material shown is available to all activities and should be used as



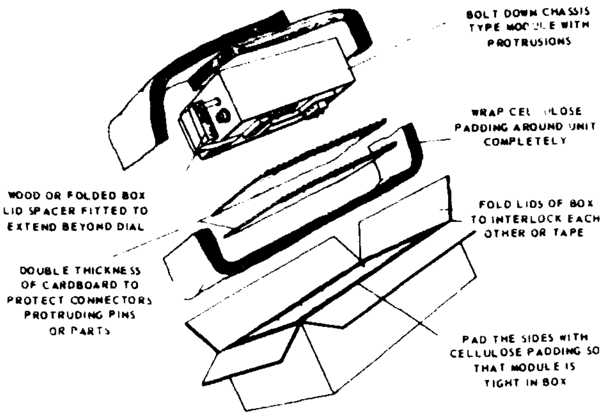
70.124

Figure 13-22.—Special soldering iron adaptations.

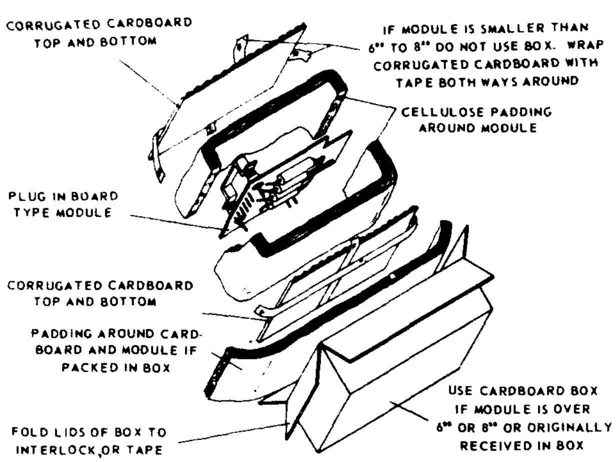


70.125

Figure 13-23.—Chassis holding jig.



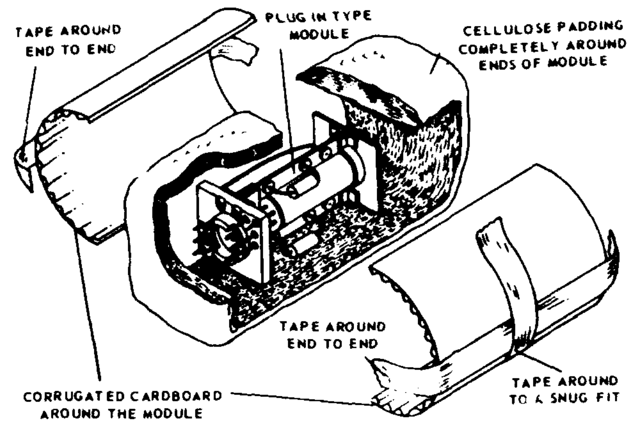
70.126
Figure 13-24.—Packaging a bolt-down chassis.



70.127
Figure 13-25.—Protective packaging of a plug-in board.

prescribed for storing or transferring defective modules until they are received by a shipping facility, which will properly package them for the trip to the factory or restoration facility.

The using activity will have done its part in preventing transport damage to the modular assembly if the pins, shafts, dials, protruding parts, and so forth, are adequately fitted with packing spacers and if the module is properly wrapped with protective cellulose (Kimpak or similar material).



70.128
Figure 13-26.—Packaging method for a plug-in module.

Desiccant crystals are normally packaged with assembled equipment crated for shipping. These are retained in a bag and placed within the crated or packaged equipment in such a manner as to prevent them from coming loose. Do not use these desiccant crystals when packaging DEFECTIVE modules. The modules must be packaged too tightly for the use of crystals in bag form, and loose crystals may cause unnecessary damage—plus a cleaning problem.

If a modular assembly becomes exposed to loose desiccant crystals, clean the assembly immediately.

Much unnecessary damage has occurred to modular assemblies because of rough handling. Particular care must be given to the method of removing or inserting a module into the equipment. If the module is a plug-in board assembly, be sure the guide pins are properly aligned before pressing the assembly in place. If the board should tilt while it is being inserted, do not continue to press it into position; straighten it, and then apply even pressure to avoid tilting. Forcing any tilted or cocked modular assembly into position may result in bent or broken pins.

When removing a modular assembly, be sure to pull it straight out from the equipment. Do not cock, twist, pry, or carelessly jerk a module or modular assembly to remove it from its mounting or connector. Sometimes it may be necessary to loosen each screw little by little consecutively to prevent damaging by cocking.

Because of the miniaturization of parts for modular construction, leads, connectors, pins, and so forth, have been stiffened to ruggedize them. As a result, these fragile parts are brittle and will break easily if bent too often or pulled on too hard. When handling a module that has been removed from its chassis, be careful not to press against the leads and pins; if a lead or pin is accidentally bent, do not try to straighten it unless it is absolutely necessary.

When repairing a modular assembly, be very careful that the tool employed does not inadvertently press against leads, pins, or other parts that are easily bent, for such pressure can destroy a good part, and cause needless repair.

One of the time-consuming elements of troubleshooting is the identification of specific components. In conventionally wired equipment, components are not always easy to locate; even the circuitry in the chassis can become confusing since related components are often positioned in decentralized areas of the chassis.

In equipment which includes printed circuit boards, identification of circuitry and components may be relatively simple; this type of circuit construction allows uniform placement of components and complete sectionalization of related circuitry. Just a quick, once-over glance of such circuitry is often all that a technician requires to formulate the overall layout of the chassis in his mind and quickly focus his attention on the area of particular concern.

Many of the commercial manufacturers have developed methods of quick identification. One of the most common ways is to impose a grid over a drawing of the board, and then furnish a table which lists the part location. Another technique is to number points of interest on the schematic, then provide a pictorial guide to locate the points on the board.

Circuit tracing of the printed wiring board may be simpler than that of conventional wiring due to increased uniformity. If the wiring board is translucent, a 60-watt light bulb placed underneath the side being traced will facilitate circuit tracing. Test points can be located in this manner without viewing both sides of the board.

Resistance or continuity measurements of coils, resistors, and some capacitors can be made from the component side of the board. In some cases, a magnifying glass will help in locating very small breaks in the wiring. Voltage measurements can be made on either side of the board. However, a needle point probe like the one in figure 13-7 is needed to penetrate the protective coating on the wiring. Hairline cracks can be located by making continuity checks as shown in Figure 13-9.

A number of general precautions are necessary when working with modular assemblies.

Observe power supply polarities when measuring the resistance of the circuits of modular assemblies containing transistors, or other semiconductors. Such parts are polarity-and voltage-conscious. Reversing the plate-voltage polarity of a triode electron tube will keep the stage from operating; but generally will not injure the tube; however, reversing the voltage applied to a transistor, or other semiconductor, will ruin it, INSTANTLY AND PERMANENTLY.

Since transistors and similar components require different power supply connections, the personnel who work with these parts must always be alert in connecting test equipment. Make sure that the correct polarity and range are observed. Recheck your work before turning on the power—the WRONG POLARITY will DESTROY the part.

GUARD AGAINST HIGH TRANSIENT CURRENT OR VOLTAGES when testing or servicing. A damaging transient pulse may be caused in a number of ways. The list that follows represents some of the most frequent accidental acts that should be and can be prevented.

1. Applying of a-c power operated test equipment or soldering iron without first making certain that power line leakage current is not excessive. Use of an isolation transformer is a good precaution to employ with all test equipment and soldering irons operated on a-c power, unless it has been determined that the equipment contains a transformer in its power supply or shows no current leakage. With all test equipment (whether transformer-operated or not), it is good practice to connect a common ground lead first from the ground of the circuit to be tested, and then to the test equipment ground.

2. Application of too high a pulse from test equipment. The safest procedure is to start with a low output signal setting, and then proceed to apply the required signal levels. Be sure that the signal applied is below the rating given for the circuit under test. Relatively high current transients can occur when test equipment is connected to a circuit where low-impedance paths exist.

3. Moving loose connections, disconnecting parts, inserting or removing transistors or

similar components, and changing modular units, while the equipment power is on or while the circuit is under test. Moving a loose connection, or any of the actions mentioned, will cause an inductive kickback (due to stray inductance, if nothing else). This can be prevented by being sure that all parts in the circuit are secure before starting the test or turning on the equipment power. Be sure to remove all possible capacitance charges from parts and test equipment before applying them to a modular assembly. When changing modular assemblies, be sure the equipment power is off.

Transistorized Training Aids

There are two general requirements for a skilled electronics technician. First, he must have a good knowledge of the theory, construction, and design features of the electronic equipment; and second, he must have sufficient mechanical skill and knowledge to successfully install, repair, and maintain the equipment. No matter how methodically and quickly the technician can locate a defect in the equipment, the final results will be unsatisfactory unless he has the necessary skill to repair the equipment in a workmanlike manner. Under proper supervision, the necessary skill can be obtained by the personnel who complete the following recommended Transistor Training Aid Program.

Transistor Training Aid Program

The training aid program calls for the construction of five transistor circuits mounted on printed wiring circuit board plug-in units similar to those used in electronic assemblies.

The training aid series in the EIB consists of five separate articles; (1) Phase I, keying oscillator (EIB 585); (2) Phase II, amplifier (EIB 586); (3) Phase III, AM radio receiver (EIB 587); (4) Phase IV, transceiver (EIB 592); and (5) Phase V, FM receiver (not yet in print). After satisfactory completion of all five phases of the training aid program, the person completing it should have acquired the experience needed to qualify him to make emergency repairs on equipment of modular or unitized construction.

The training aids to be built during this program will be duplicates of modular or unitized units in parts, material, and compactness, and their construction will involve most of the problems encountered in the repair of this type of equipment.

Additional procedures and techniques are also included in this training aid program, to give participating personnel further insight into the principles employed in the design and fabrication of a printed circuit.

An additional source of information that will acquaint repair facility personnel and ship's electronics technicians with some of the more important techniques required for the repair and restoration of electronic assemblies is currently appearing in the EIB entitled "Repair and Maintenance Techniques for Electronic Assemblies." This series consists of eight articles, the first appearing in the 3 January 1961 (551A) issue. Article numbers two through eight are contained in the following EIBs—552, 553, 566, 567, 568, 569, and 570. It is recommended that these articles be read by all who are participating in the training aid program, and before attempting to repair electronic assemblies. These articles also serve as an educational guide for a better understanding of the techniques and procedures required in the design, mounting, and soldering of minature and subminiature components onto plug-in board assemblies similar to those used in the training aid program.

APPENDIX I

TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title the training films are identified by Navy number and title and are briefly described. Other training films that may be of interest are listed in the United States Navy Film Catalog. NavPers 10000 (revised).

Chapter 2

ELECTRONICS SAFETY PRECAUTIONS

MC 4597 For Safety's Sake. (13 min—B&W—Sound—Unclassified—1945.) Explains necessary precautions in handling power tools with emphasis on drills, grinders, and electric saws. Stresses importance of wearing goggles, keeping equipment in good condition, and grounding equipment. Uses actual accidents to demonstrate results of carelessness.

MN 6754 Safety Precautions For Electronics Personnel-Introduction. (15 min.—B&W—Sound—Unclassified—1951.) Shows electrical and mechanical hazards which electronics technicians encounter in normal work and stresses precautions which should be used to prevent accidents. Film content includes procedures for working on energized and deenergized circuits, handling of cathode-ray tubes, preventive measures aboard ship, and the hazards of carelessness and practical jokes. Sresses necessity for cultivation of safe working habits.

MN 8990 115 Volts—Deadly Shipmate. (19 min.—Color—Sound—Unclassified—1960.) This film tells the story of Joe who is representative of all sailors and is based upon the reenactment of actual cases. It emphasizes the disastrous effects of low-voltage electrical shock when the basic rules of electrical safety are violated or ignored.

SC 8358 This Will Kill You. (20 min.—Color—Sound—Unclassified.) Shows many of the casualties and fatalities; explains current, heat burns, first aid, difference between effects of a-c and d-c damage, and has a summary based upon a variety of case histories. All of the major "do's" and "don'ts" of electrical accidents are forcefully presented.

SA 7810 Hazards of High Powered Radio Transmitters. (51 Frames—B&W—Silent—Unclassified—1951.) Emphasizes the ever-present danger of shock and burns from high-powered radio equipment.

Chapter 5

ELECTRONIC INSTALLATION

MN-7848-E Search and Height Finding Radar—the AN/SPS-8 Introduction. (19 min.-B&W-Sound-Unclassified-1954.) General overall description of the AN/SPS-8 radar.

MN-8099-A Radio Teletype Systems Afloat—General Principles of Operation. (15 min.-B&W-Sound-Unclassified-1956.) Explains the reasons for radio teletype systems afloat, and describes briefly two different systems of transmitting and receiving.

MN-2565-A Transmission Lines—Maintenance of the Coaxial Line. (28 min.-B&W-Sound-Unclassified-1944.) Description of the construction and principles of replacing and repairing coaxial transmission lines.

MN 6525-C Ground Aids to Air Navigation (Ship to shore). (19 min.-B&W-Sound-Unclassified 1955.) Shows the theory and operation of TACAN.

Chapter 6

APPLICATION OF TEST EQUIPMENT

MA-7812A Circuit Testing with Meters and Multimeters—Theory. (35 min.—B&W—Sound—Unclassified—1951.) US Army TF11-1666. Describes the basic principles of meters and multimeters and illustrates their use in the operation and maintenance of communications equipment. Largely, through the medium of animation photography, the steps in building a meter are delineated. Included are voltmeter, vacuum tube voltmeter, ohmmeter, tube-tester, and wattmeter. The general purpose multimeter is described as a combination of several meters. In radio, telephone, and teletypewriter troubleshooting, the meter is the most important and useful tool available.

MA-7812B Circuit Testing with Meters and Multimeters—Practical Applications. (33 min.—B&W—Sound—Unclassified—1951.) US Army TF11-1667. Meters and multimeters are indispensable in the operation, maintenance and repair of electronic equipment. The equipment described includes: Volt-Ohm-Milliammeters, the Wheatstone Bridge, decibel meter and the tube tester. A step by

step procedure for using these meters is shown, followed by a description of how they are used in testing transformers, capacitors, resistors, telephone loop circuits, etc. It is emphasized that the technicians should read the operating manuals for this equipment, and keep them handy for the reference purposes. Rigorous safety practices should be followed at all times. The film ends by stressing care of meters to preserve their accuracy.

MN-8687B Reading Multimeter Scales. (6 min.—B&W—Sound—Unclassified—1956.) US Army TF11-2392. Multimeter scales must be read correctly for effective use of the instrument in radio repair. All multimeters have similar scales. Using a typical multimeter, this film demonstrates how to read the scales to measure direct current, DC voltage, AC voltage, and resistance.

MA-8688 Use of Signal Generator AN/URM-25D. (7 min.—B&W—Sound—Unclassified—1957.) US Army TF11-2441. The signal generator is an instrument designed to generate AC signals suitable for test purposes. It is used for trouble shooting or aligning signal communication equipment. This film explains and demonstrates the correct use of Signal Generator AN/URM-25D.

MN-1540Q Radio Technician Training—Signal Generator Operation. (9 min.—B&W—Sound—Unclassified—1945.) Use of signal generator in receiver alignment is subject of the picture. Use of modulation switch, adjustments needed to secure various frequencies (for example 456kc and 87MC) and use of alternator switch is shown. Voltmeter gives visual check of adjustments while earphones provide audio alignment check.

MN-1540P Radio Technician Training—Tube Tester Operation. (9 min.—B&W—Sound—Unclassified—1944.) Shows testers designed to check (1) cathode emission, and (2) dynamic mutual conductance of tube. Emphasize use of instruction book supplied with tester and of the tube manual. Testers are practically fool proof. Simply turn index scale to number of tube being tested and follow lines to operate appropriate control of push button.

MN-1540R Radio Technician Training—Audio Oscillator Operation. (9 min.—B&W—Sound—Unclassified—1945.) Explains operation of audio oscillator and demonstrates use. Performance of audio oscillator is shown by checking an amplifier with the audio oscillator and "A" scope illustrates and explains all knob turning.

SN-658 Making Frequency Measurements with the CFI. (39 frames—B&W—Silent—Unclassified—1942.) Describes steps in measuring radio wave frequency with the LM-CF1.

Chapter 7

USE OF EQUIPMENT

MN 2104B — The Cathode Ray Oscilloscope. (23 min.—B&W—Sound—Unclassified—1944.) Explains wide application of the cathode ray in making instantaneous graphs of the wave form of an electric current. Shows use of vertical amplifiers, horizontal amplifier, sweep generator which furnishes the time base cathode ray tube, and power supply. Illustrates the use of the course and fine sweep circuit to synchronize signals so that wave form is stationary.

MN-2104A — The Cathode Ray Tube-How it Works. (15 min.—B&W—Sound—Unclassified—1943.) Demonstrates construction and function of each part of the cathode ray tube and how it produces visual images on a screen. Explains electrostatic deflection, electro-magnetic deflection, and how varied currents affect position of the spot of light on the scope.

SN-657 — Calibrating the Type LM Crystal Frequency Indicator. (42 frames—B&W—Silent—Unclassified—1942.) Demonstrates calibration of type LM Crystal Frequency Indicator.

MN-1540S — Radio Technician Training—Volt-Ohmmeter Operation. (15 min.—B&W—Sound—Unclassified—1944.) Demonstrates use of various types of volt-ohmmeters, (including the electronic meter) and gives cautions to be followed, such as using the large scale first, (R x 1000; R x 10; R ranges available) and connecting the voltmeter in parallel (Scales; 600, 300, 30, 3 volts).

Chapter 8

SWITCHES, SWITCHBOARDS, AND SWITCHING SYSTEMS

MN-6836 — Shipboard Radio Communications-Remote Control transfer Switchboards. (11 min. B&W-sound-unclassified-1955.) Describes communication switch type remote control transfer switchboards.

Chapter 9

COMMON OPERATING ADJUSTMENTS—RADIO TRANSMITTING AND RECEIVING

MN-8086A — Radio Transmitting Sets AN/URT 2,3,4—Introduction. (15 min.—B&W—Sound—Unclassified—1955.) Shows the units that comprise the three transmitters, the capabilities of each and how they are operated in a normal automatic condition including the setting up of ten channel frequencies. Procedures for semi-automatic and manual tuning are also shown.

MN-8086B Radio Transmitting Sets AN/URT 2, 3, 4—The RF Oscillator. (17 min.—B&W—Sound—Unclassified—1955.) Shows how the AN/URT series of transmitters generate and modulate carrier frequencies. Describes how the various circuits multiply, add, and subtract frequencies to produce the final carrier frequency, and how the frequency is amplified in the RF Amplifier and modulated in the Low Level Radio Modulator for voice or key modulation.

MN-8086C Radio Transmitting Sets AN/URT 2, 3, 4—The RF Amplifier and Modulator. (7 min.—B&W—Sound—Unclassified—1955.) Shows how the frequency is amplified in the RF Amplifier and modulated in the Low Level Radio Modulator for both voice and various types of keying modulation.

MN-8086D Radio Transmitting Sets, AN/URT 2, 3, 4—Automatic Frequency Selection. (14 min.—B&W—Sound—Unclassified—1955.) Shows how the telephone-type dial controls the automatic frequency-selection circuit for switching the R-F Oscillator to the pre-set frequency.

MN-8086E Radio Transmitting Sets, AN/URT 2, 3, 4—Automatic Bandswitching. (7 min.—B&W—Sound—Unclassified—1955.) Shows how the Radio Frequency Amplifier divides the frequency range into six different bands and how the bandswitch motor automatically selects the band that includes the carrier frequency.

MN-8086F Radio Transmitting Sets, AN/URT 2, 3, 4—Automatic Amplifier Tuning. (18 min.—B & W—Sound—Unclassified—1955.) Shows how the automatic amplifier tuning circuits tune the Intermediate Power Amplifier and the Power Amplifier.

MN-8086G Radio Transmitting Sets, AN/URT 2, 3, 4—Automatic Antenna Tuning. (18 min.—B & W—Sound—Unclassified—1955.) Shows how the RF tuner and capacitor assembly automatically tunes the antenna to the frequency that has been selected for transmitting. This is the last of four automatic tuning operations that take place when a new transmitting frequency has been selected.

Chapter 10

COMMON OPERATING ADJUSTMENTS—TELETYPE AND FACSIMILE

MN-8099A Radio Teletype Systems Afloat—General Principles of Operation. (15 min.—B&W—Sound—Unclassified—1956.) Explains the reason for radio teletype systems afloat and describes briefly two different systems of transmitting and receiving.

MN-8099B Radio Teletype Systems Afloat—Tone Modulated System. (11 min.—B&W—Sound—Unclassified—1956.) Describes operation of the tone-modulated system for short range radio teletype transmitting and receiving system.

MN-8099C Radio Teletype Systems Afloat—Carrier Frequency Shift Transmitting System. (6 min.—B&W—Sound—Unclassified—1956.) Describes the long-range Frequency Shift Transmitting System used in shipboard radio teletype systems.

MN-8099D Radio Teletype Systems Afloat—Carrier Frequency Shift—Receiving System. (10 min.—B&W—Sound—Unclassified—1956.) Explains simply the reason and operation of radio frequency shift system for radio teletype systems afloat.

Chapter 11

COMMON OPERATING ADJUSTMENTS—RADAR AND LORAN

SN-1083 Knob Turning—Radar No. 13. (53 frames-B&W—Silent—Unclassified—1942.) Illustrates how to turn on and properly tune equipment, set focus and brilliance controls, set antenna switches to homing, and proper method of reporting an object and turning off equipment.

SN-2357D Loran—Principles of Operation. (70 frames—B&W—Sound—Unclassified—1944.) Describes the three basic parts of Loran: Transmitters on land; receiving and time measuring equipment; and plotting charts. Explains how the chart hyperbolas are constructed on the basis of a slave station emitting signals at definite time interval (somewhat more than 20,000 microseconds) after the master station emits its signal. Differentiates between ground waves (500-700 miles) and sky waves (1500 miles at night.)

SN-2357E Loran—Alignment and Calibration. (66 frames-B&W—Silent-Unclassified-1944.) Shows checks on alignment to be made before takeoff and before taking readings. Also covers checks on calibration of the delay, coarse and fine signal adjustments.

SN-2357F Loran—Taking a Reading and Plotting a Fix. (43 frames-B&W-Silent-Unclassified-1944.) Shows five steps in getting a time distance reading: selecting signals from one pair of stations; making the coarse delay adjustment; making the day fine delay adjustment; and recording data. Then selecting a pair of signals from two other stations. Finally finding the hyperbola for reading of the first pair; finding the same for the second pair; and interpolating. Corrections are applied for sky waves and security time delay.

Chapter 12

MAINTENANCE PROCEDURES AND TECHNIQUES—PART I

MA-8927A Radio Interference-Part I. (23 min.—B&W—Sound—Unclassified-1958.) Explains the significance of radio interference and the manner in which it is produced.

MA-8369 Calibrating and Tuning Radio Set AN/PRC-10. (9 min.-B&W-Sound-Unclassified-1955.) US Army TF 11-2181. Teaches the step-by-step procedure for calibrating and tuning Radio Set AN/PRC-10.

MA-8862D Radio Set AN/GRC-26-Part 4—Setting up Receiver as Frequency Standard. (15 min.—B&W—Sound—Unclassified-1958.) US Army TF 11-2563. This film portrays the step by-step procedure to set up Receiver "A" as a frequency standard. A demonstration frequency of 4280 kc is used.

MA-8927B Radio Interference-Part II. (37 min.—B&W—Sound—Unclassified—1958.) Shows how sources of radio interference can be tracked down, and how various kinds of interference are suppressed.

MA-8681A Environmental Factors Affecting Reliability of Electronic Equipment. (17 min.—B&W—Sound—Unclassified—1956.) Presents the effect of naval shipboard environments on the reliability of electronic equipments.

Chapter 13

MAINTENANCE PROCEDURES AND TECHNIQUES—PART II

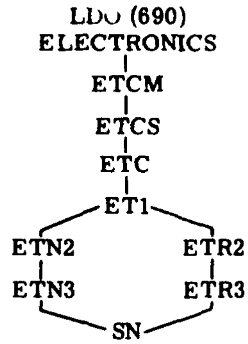
MN-8086H Radio Transmitting Sets AN/URT 2, 3, and 4—Troubleshooting. (12 min.—B&W—Sound—Unclassified—1955.) Shows how to determine the general location of trouble in the AN/URT series of transmitters. Describes the use of various lights and meters to locate trouble, the built-in test oscilloscope for testing the operation of the internal oscillators and finally the external test equipment.

MN-8572 Moistureproofing Electrical "AN" Type Connectors. (20 min.—Color—Sound—Unclassified—1957.) Shows "potting" process.

APPENDIX II
QUALIFICATIONS FOR ADVANCEMENT IN RATING

ELECTRONICS TECHNICIAN (ET)

Quals Current Through Revision A



CAREER PATTERN

GENERAL RATING (PO1 and CPO)

SCOPE

Electronics Technicians maintain, repair, calibrate, tune, and adjust electronic material (except airborne and weapon-control equipment) used for communication (except interior communication systems and teletypewriters) detection and tracking, recognition and identification, aids to navigation, and electronic countermeasures.

SERVICE RATINGS (PO3 and PO2)

SCOPES

ELECTRONICS TECHNICIAN N (Communications) . . . . ETN

Electronics Technicians (N) maintain, repair, calibrate, tune, and adjust communications equipment, radio aids to navigation and radio countermeasures equipment, including radio and facsimile equipment, teletype and similar types of terminal equipment, data transmission systems, radio direction finding and loran receiving equipment, and radio beacons.

ELECTRONICS TECHNICIAN R (Radar) . . . . ETR

Electronic Technicians (R) maintain, repair, calibrate, tune, and adjust electronic sea, land, and air detection and tracking equipment, electronic recognition and identification equipment and radar countermeasures equipment, including search radar and radiac equipment, IFF systems, and racons.

QUALIFICATIONS FOR ADVANCEMENT	Required for Advancement to ETN	ETR	ET
A. SAFETY			
1.00 Practical Factors			
.01 Demonstrate under simulated conditions the rescue of a person in contact with an energized electrical circuit, resuscitation of a person unconscious from electrical shock, and treatment for burns.	3	3	–
.02 Demonstrate, while servicing equipment, safety precautions such as tagging switches, removing fuses, and grounding test equipment, using shorting bars and rubber mats	3	3	–
2.00 Knowledge Factors			
.01 Effects of electrical shock, methods of resuscitation of a person unconscious from electrical shock, and treatment for burns	3	3	–
.02 Electrical and electronic safety precautions (except those applicable exclusively to line construction) as set forth in Chapter 18, U. S. Navy Safety Precautions (OpNav 34P1)	3	3	–

B. ELECTRICITY AND ELECTRONICS

1.00 Practical Factors

None.

QUALIFICATIONS FOR ADVANCEMENT B. ELECTRICITY AND ELECTRONICS—Continued	Required for Advancement to ETN	 ETR	 ET
2.00 Knowledge Factors			
.01 Definition and usage of common electrical, magnetic, and electronic terms including:			
a. Volt, ohm, ampere, watt, volt-ampere, henry, and farad	3	3	–
b. Cycle, ampere-turn, coulomb, circular mil, conductor, insulator, field intensity, and flux density	3	3	–
c. Gauss, permeability, hysteresis, eddy current, reactance, impedance, capacitance, inductance, self-inductance, and mutual and electromagnetic inductance	3	3	–
d. Power factor, frequency, phase, RC time, attenuation, absorption, and conductance	3	3	–
e. Modulation, demodulation, detection, selectivity, sensitivity, and class A, B, C, and AB amplifiers	3	3	–
f. Filter, intermediate frequency, heterodyne, node, resonance, and nonlinear	3	3	–
g. Sideband, single sideband, zero beat, AGC, and ganged tuning	3	3	–
.02 Interpretation of RETMA color coding of fixed capacitors and resistors and power, AF, and IF transformer connections	3	3	–
.03 Calculation of current, voltage, and resistance in d.c. series and parallel circuits containing not more than four elements	3	3	–
.04 Relationship of length and cross-sectional area to resistance of a conductor	3	3	–
.05 Relationship of resistance, temperature, and current in an electrical conductor	3	3	–
.06 Methods of obtaining three general types of bias-fixed, cathode, and grid leak	3	3	–
.07 Construction of a.c. and d.c. motors and generators; application of laws of magnetism to electrical rotating machinery	3	3	–
.08 Function of components in electrical/electronic circuits serving as resistors, rheostats, potentiometers, solenoids, inductors, relays, capacitors, fuses, switches, reactors, transformers, and crystals	3	3	–
.09 Types, structure, maintenance procedures, and electrical characteristics of batteries	3	3	–
.10 Function of elements used in vacuum tubes	3	3	–
.11 Relationship of current, voltage, and impedance in a.c. circuits	3	3	–
.12 Calculation of current, voltage, phase, angle, impedance, power factor, and resonance in a.c. series and parallel circuits containing not more than four elements	3	3	–
.13 Meaning of cathode ray tube presentations on electronic equipment	3	3	–
.14 Cause and/or effect of sky, ground, and ground-reflected waves, and ionospheric reflecting layers on propagation	3	3	–
.15 Electrical characteristics of Hertz, Marconi, and dipole antennas	3	3	–
.16 Function and operating principles of components of a typical pulse radar set; timer, modulator, transmitter antenna, receiver, and indicators	–	3	–
.17 Function and operating principles of:			
a. Stages of a typical radio transmitter; master oscillator, modulator, power amplifier, and antenna	3	–	–
b. Stages of a typical superheterodyne receiver; antenna, RF amplifier, oscillator, mixer, IF amplifier, detector, AF amplifier, and speaker	3	–	–

QUALIFICATIONS FOR ADVANCEMENT

B. ELECTRICITY AND ELECTRONICS—Continued

	Required for Advancement to ETN	ETR	ET
2.00 Knowledge Factors—Continued			
c. Antenna couplers and remote control patching systems	3	—	—
.39 Function and operating principles of the following:			
a. Audio, video, RF, and IF amplifiers	3	3	—
b. Oscillators: tickler-feedback, Colpitts, ultra-audion, TPTG, push-pull, electron-coupled, transistron, Hartley-crystal controlled and basic multivibrator	3	3	—
c. Rectifiers: copper oxide, selenium, silicon diodes, crystal, and electron tube	3	3	—
d. Detectors: diode and crystal	3	3	—
e. Tuned coupling and AGC circuits	3	3	—
f. Impedance matching, phase shifters, cathode followers, limiters and clippers, sawtooth generators, and phase inverters	3	3	—
g. Modulation: amplitude, frequency, phase and pulse; grid, screen, and plate	3	3	—
h. Coaxial transmission lines	3	3	—
i. Differentiators and integrators, peakers, discriminators, clampers, and transistors	2	2	—
j. Oscillators: blocking and Wein-bridge	2	2	—
k. Trigger, coincidence, AFC, counting, and phase splitting circuits	2	2	—
l. Paraphase and magnetic amplifiers	2	2	—
m. Modular construction	2	2	—
n. Vacuum tubes, gas-filled tubes, cathode ray tubes and magnetrons	2	2	—
o. Special purpose tubes such as traveling wave, carcinotrons, and high-powered klystron amplifiers	—	—	1
.40 Operating principles of basic meters and meter movements employing the following:			
a. D'Arsonval and electrodynamometer movements	2	2	—
b. Shunts and multipliers	2	2	—
c. Thermocouples and rectifiers in a.c. meters	2	2	—
.41 Operational capabilities and limitations of electronic equipment	2	2	—
.42 Method of connecting moving element to resistors to form voltmeter or ammeter; meaning of meter sensitivity and effect of circuit loading	2	2	—
.43 Computations required to determine size of shunts and multipliers	2	2	—
.44 Characteristics and use of synchros and servomotors; methods of setting to electrical zero; purpose of gain, phase, and balance adjustments	2	2	—
.45 Function and operation of the following:			
a. Electronic switch, synchroscope and spectrum analyzer	2	2	—
b. Absorption wavemeter, grid dip and radio-interference field-intensity meters	2	2	—
.46 Applications and basic principles of wave guides, T/R and AT/R tubes, klystrons and magnetrons, crystal mixers, and radar modulators	2	2	—
.47 Cause and/or effect of an induction field and radiation field	2	2	—
.60 Operating principles and radiation characteristics of parabolic and lens antennas	—	—	1
.61 Operating principles and characteristics of, and repairs and calibrations authorized on, electronic test equipment in items D1.01 and B2.45	—	—	1

QUALIFICATIONS FOR ADVANCEMENT	Required for Advancement to		
B. ELECTRICITY AND ELECTRONICS—Continued	ETN	ETR	ET
2.00 Knowledge Factors—Continued			
.80 Theory of single sideband radio transmission and reception	–	–	C
.81 Polarization and directional characteristics of antenna arrays such as driven arrays (collinear), parasitic arrays (Yagi), parabolic, corner or flat reflectors, phased arrays, waveguide, and type antennas	–	–	C
C. OPERATIONAL MAINTENANCE			
1.00 Practical Factors			
.01 Inspect, clean, and lubricate electronic equipment in accordance with technical publications	3	3	–
.02 Test and/or replace plugs, lamps, fuses, switches, electron tubes, jacks, cables, and wiring	3	3	–
.03 Select, use, and maintain handtools and small portable power tools necessary for maintenance and repair of electronic equipment	3	3	–
.04 Perform operational tests and make external adjustments on electronic equipment	3	3	–
.05 Utilize distribution patching system for radio transmitters, receivers, and antennas for all local and remote operation positions	3	3	–
.06 Inspect and clean commutators and slipring assemblies; inspect and replace brushes	3	3	–
.07 Make electrical connections and splices including soldering joints	3	3	–
.08 Manipulate external controls; read and interpret dials, meter indications, and cathode ray tube presentations on electronic equipment	3	3	–
.09 Read schematic wiring diagrams of electrical and electronic circuits; identify and interpret electrical, electronic, and mechanical symbols shown in electronic technical maintenance publications and installation blueprints	3	3	–
2.00 Knowledge Factors			
.01 Importance of using proper lubricants and solvents in maintenance of electronic equipment	3	3	–
.02 Purpose of operator's controls and adjustments such as:			
a. Receiver gain, transmitter tuning and antenna tuning	3	3	–
b. Radar intensity, focus, receiver tuning, antenna rotation, range, and IFF interrogation switch, loran sweep speed switch, and coarse and fine delay	–	3	–
.80 Effects of environmental conditions upon operation of electronic and electrical equipment and special maintenance techniques involved for equipment to be operated at extreme temperature and humidity	–	–	C
D. TECHNICAL MAINTENANCE			
1.00 Practical Factors			
.01 Demonstrate use of the following test equipment:			
a. Electronic and nonelectronic multimeters	3	3	–

QUALIFICATIONS FOR ADVANCEMENT

D. TECHNICAL MAINTENANCE—Continued

		Required for Advancement to ETN	ETR	ET
1.00	Practical Factors—Continued			
	b. Tube tester, oscilloscope, and AF signal generator	3	3	—
	c. Capacitance-inductance-resistance bridge	3	3	—
	d. RF signal generator, frequency standards, and megohmmeter	3	3	—
	e. Range mark generator and echo boxes	—	3	—
.02	Make tests for short circuits, grounds, and continuity of interconnecting cables between components of electronic equipment	3	3	—
.03	Localize equipment casualties to components of a system of electronic equipment	3	3	—
.04	Locate and identify components, assemblies, subassemblies, and primary and casualty power circuits of electronic equipment by reference to technical maintenance publications, block diagrams, and installation blueprints	3	3	—
.05	Locate in technical and maintenance publications information necessary for maintenance and repair of electronic equipment; enter corrections to publications when changes are made	3	3	—
.40	Effect authorized field changes to electronic equipment in accordance with instructions and diagrams	2	2	—
.41	Operate the following test equipment:			
	a. Electronic switch and spectrum analyzer	2	2	—
	b. Synchroscope	—	2	—
	c. Absorption wavemeter, grid dip, and radio-interference field-intensity meters	2	2	—
.42	Test electronic circuits for continuity, short circuits, and grounds; measure electrical quantities such as voltage, current, power, and frequency, and compare with established values; use an oscilloscope to view circuit waveforms and compare with established optimum performance waveforms required in electronic equipment	2	2	—
.43	Perform sensitivity and selectivity measurements and aline circuits as necessary for optimum performance of electronic equipment	2	2	—
.44	Localize electronic equipment casualties to parts or subassemblies; repair by replacement of subassemblies or parts	2	2	—
.45	Repair multimeters, oscilloscopes, test oscillators, and signal generators	2	2	—
.46	Perform tests, adjustments, and repairs necessary for proper operation of electromechanical servomechanisms and synchro control circuits including:			
	a. Electrical zeroing of synchros	2	2	—
	b. Testing servomotors and amplidynes	2	2	—
	c. Gain, phase, and balancing adjustments	2	2	—
.60	Repair countermeasures equipment	—	—	1
.61	View and compare with established standards, waveforms of the following circuits: Squaring and peaking, clamping circuits, high vacuum tube sweep generators (hard tube type), trapezoidal sweep generator, phantastrons, blocking oscillators, and counting circuits	—	—	1
.62	Aline circuits by synchronizing multivibrators or blocking oscillators with sine wave, positive pulses, or submultiples of trigger frequency, or negative pulses	—	—	1
.63	Analyze and evaluate electrical and electronic tests; make adjustments, calibrations, and repairs necessary for optimum performance of electronic equipment	—	—	1

QUALIFICATIONS FOR ADVANCEMENT	Required for Advancement to ETN	ETR	ET
D. TECHNICAL MAINTENANCE—Continued			
1.00 Practical Factors—Continued			
.64 Evaluate test equipment for correct operation; make authorized repairs and calibrations	—	—	1
.79 Adjust antenna arrays such as: Driven arrays (collinear), parasitic arrays (Yagi), parabolic, corner, or flat reflections back of dipoles, phased arrays, and waveguide type antennas for:			
a. Traffic requirements	—	—	1
b. Environmental conditions	—	—	C
.80 Test and evaluate for proper and secure installation and optimum performance, newly installed or overhauled components assemblies, or subassemblies of electronic equipment	—	—	C
2.00 Knowledge Factors			
.01 Method of soldering and soldering equipment used in maintenance and repair of electronic equipment	3	3	—
.40 Application of oscilloscope waveform analysis to location of circuit malfunctions	2	2	—
E. ELECTRONICS ADMINISTRATION			
1.00 Practical Factors			
.01 Record test data and work accomplished in required work logs, equipment histories, and checkoff lists	3	3	—
.02 Take, record, and report inventories of tools and portable test equipment available for maintenance and repair of electronic equipment	3	3	—
.03 Prepare Current Ship's Maintenance Project (CSMP)	3	3	—
.40 Gather information for, and prepare and complete entries in, electronic equipment failure reports	2	2	—
.41 Prepare job orders and work requests	2	2	—
.42 Obtain part and stock numbers from technical and supply publications for tools and replacement parts; procedures for requisitioning such material	2	2	—
.60 Prepare and complete periodic or recurring reports concerning performance and/or maintenance of electronic equipment	—	—	1
.61 Inspect completed work logs and checklists; review electronic equipment failure reports, requisitions for tools and replacement parts, inventories of tools and portable test equipment, job orders, and work requests	—	—	1
.62 Supervise and train personnel in maintenance and repair of radio, radar, and countermeasures equipment	—	—	1
.80 Qualify individual operators to carry out authorized performance standards tests on electronic equipment to which assigned	—	—	C
.81 Evaluate complete electronic equipment failure reports, requisitions for tools and replacement parts, inventories of tools and portable test equipment job orders, work requests, electronic equipment histories, and periodic or recurring reports concerning performance and/or maintenance of electronic equipment	—	—	C
82 Organize and administer maintenance and repair of electronic equipment	—	—	C

QUALIFICATIONS FOR ADVANCEMENT

E. ELECTRONICS ADMINISTRATION—Continued

	Required for Advancement to ETN	ETR	ET
2.00 Knowledge Factors			
.01 System of assigning "AN" letter-number combinations as designation for electronic equipment	3	3	–
.02 Types of information contained in electronic technical and maintenance publications	3	3	–
.60 Methods, techniques, and devices applicable in electronic maintenance training of teams and individuals	–	–	1
.80 Procedures for accounting for electronic equipment, maintaining control of inventories and workflow, and reporting equipment status and work accomplished	–	–	C
.81 Current bureau directives on operational and maintenance responsibilities of enlisted personnel for electronic equipment	–	–	C

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